A MATHEMATICAL PROGRAMMING MODEL FOR FARM HOUSEHOLD EVALUATION: ECONOMIC EFFICIENCY ANALYSIS OF FARMS UNDER RISK AND UNCERTAINTY IN MOZAMBIQUE

By

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Farmers in Mozambique produce under a relatively high degree of risk and uncertainty for their scale of activity. They have low yields, and their production barely meets subsistence requirements. Increased farm production is seen as an important goal for securing food supplies.

This study evaluates allocation of household resources, analyzes agricultural techniques adopted by farmers of Xai-Xai, searches for alternative solutions to food insecurity, and develops a mathematical programming model for farm household evaluation. A survey of 110 households was done in Xai-Xai in 1992, data were collected on production techniques, input use, production constraints, household consumption, and market prices.

The farm household model was tested and simulations of price changes were done to evaluate, ex-ante, their impact on farm households. The solutions of the model were consistent

with prevailing production cropping systems in Xai-Xai.

The results of the survey indicate that the major problems faced by the households in Xai-Xai are drought, famine, lack of farm credit, schools and hospitals. Their objective function includes food security and optimization of net incomes.

Due to a high yield variability of new varieties of maize and peanuts, irregular supply of fertilizer and pesticides at affordable prices, farmers prefer to continue growing low risk varieties to assure minimum food requirements. Unfortunately those varieties have low yields and cannot provide sufficient food to cope with increasing population.

Price adjustments are not sufficient to achieve a sustained supply response from a large and growing number of poor households. Price increases result in a change of crop composition rather than an overall increase in output. Poor farmers lose access to inputs and new technologies, and they will tend to increase the area for subsistence crops.

These findings suggest that future programs must be targeted to reduce risk and uncertainties in agriculture, provide alternative sources of farm credit, and promote educational opportunities along with extension services.

CHAPTER 1
THE PROBLEM SETTING

Introduction

As we approach the twenty-first century, developing countries are facing challenges of increasing population, severe drought, famines, reduced investments, and high foreign debt. Agriculture is the major economic activity for large populations of the developing world, especially in Africa. Productivity in agriculture is relatively low and agricultural commodity prices show a declining trend for many export crops. The assumption held three decades ago that industrialization was the main hope of the developing countries has undergone remarkable changes. Now, there is a belief that agriculture and rural development are the "sine qua non" for any successful development program.

In Africa, the food situation has deteriorated over the past twenty years. In Mozambique, Ethiopia, and Somalia food supplies have become seriously degraded. Population growth rate has ranged from 2.6 to 3.5 % per year. The international economy and foreign trade policies are not favorable, and instead of helping the continent to develop, they add to the already existing problems. Most African countries increasingly are unable to provide services for rural

development and also have been obliged to cut subsidies for basic foodstuffs with immediate negative effects on the rural poor. Mozambique is among those countries facing a crisis.

This study focuses on agriculture and its contribution to the economic development of Mozambique. Special attention is directed to the assessment of farm household and agricultural policies. There is no simple explanation for the current economic crisis in Mozambique. External, internal, and environmental factors are the causes of the current economic crisis in Mozambique. By analyzing farm households we can better understand decisions concerning what should be produced, when production should take place, and how production should be distributed in the household. There is a need for more research in production techniques before attempts are made to change existing production techniques.

In Mozambique, rural households are the basic units of the agricultural system. Households are the decision-making units that manage agricultural resources such as land and family labor. They hire outside labor and purchase inputs to produce foodstuffs for subsistence and the market. A majority of rural households in the country are involved in subsistence agriculture which is highly risky in outcomes and has great uncertainty in prices and policies. A very small part of the rural population consists of wage laborers.

Country Background

Mozambique is a southern African country with approximately 17 million inhabitants (Mozambique government 1993). It became independent from Portugal in 1975. Figure 1.1 show the location of Mozambique in Africa.

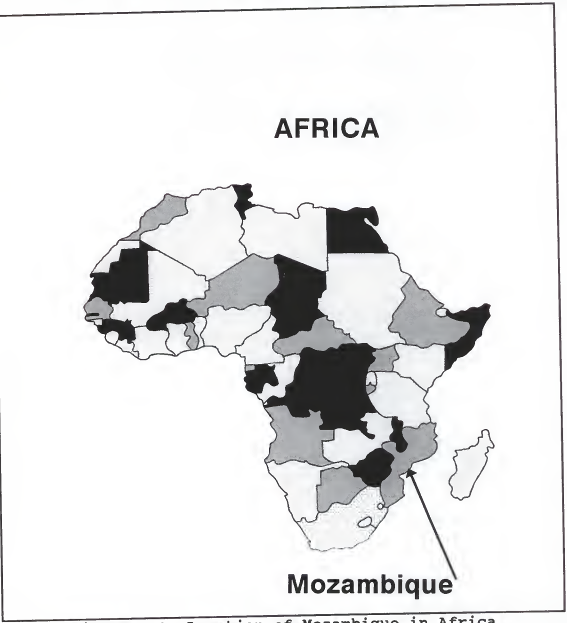

Figure 1.1. Location of Mozambique in Africa

Portuguese is the official language. However, only 1.2% of the population speak Portuguese as a mother tongue, 11.8% speak Portuguese as well as their native language, and 87% do not speak Portuguese. Most people speak one or more African languages. Forty-two percent of the population speak Makua, 27% speak Tsonga, 7 to 9% speak Nyaroja/Sena and 5 to 7% speak Shona.

The estimated land area is 799,830 square kilometers. The Indian Ocean coastline is 2,470 kilometers long. To the north, Mozambique borders Tanzania; to the west, Malawi, Zambia and Zimbabwe, and to the south, Swaziland and the Republic of South Africa, with a land border of 4,330 kilometers.

There is no official religion in Mozambique. During colonial times, many Mozambicans were converted to Catholicism. Between 1910 and Independence in June 25, 1975, separatist churches, mainly Zionist Ethiopian, became centers of resistance to Portuguese rule and, by 1938, 380 such churches were known to exist. Currently, many people in the North, including the Swahili and Yao are still Muslim, as they have been for centuries. Most rural people adhere to their traditional polytheistic beliefs, while urban Mozambicans tend to be Christians, either Catholic or Protestant.

The infant mortality rate for the period 1975-1980 was 159 per 1,000, but because of war it rose sharply in 1989 to 173 per 1,000. The number of annual births is about 571,808.

More than 40% of the population is under the age of 15 and more than 70% is under 30 years old. The average life expectancy at birth is 43.6 years.

The distribution of population and the population density is shown in the Table 1.1.

Table 1.1. Distribution and Density of Population, 1989

Province	Area (Square Km)	Population (Thousands)	Density (pop/Sq.km)
Niassa	129 056	651.2	5.0
Cabo Delgado	82 625	1 190.0	14.4
Nampula	81 606	3 028.0	37.1
Zambézia	105 008	3 137.2	29.9
Tete	61 661	1 052.2	17.1
Manica	68 018	800.7	11.8
Sofala	100 724	1 337.7	13.3
Inhambane	68 515	1 254.4	18.3
Gaza	75 707	1 221.8	16.1
Maputo Prov.	26 058	875.1	33.6
Maputo city	300	778.5	2 595.0
Total	799 380	15 326.8	19.2

Source: Comissäo Nacional do Plano, Informaçäo Estatística, 1990.

At independence, 93% of the population was illiterate, but due to literacy campaigns after 1975, the rate of illiteracy declined to 61% in 1993. In the area of health care services, it is important to note that the number of doctors increased from 171 in 1975 to 317 in 1985, with 12,000 people per health post, and one doctor for every 44,000 people. The number of health posts and centers increased from 326 to 1,178 during the same period. According to the Ministry of Health, in April of 1990, 978 health units had

been destroyed or forced to close due to the war, which ended in October of 1992.

Debates on agricultural and economic development in Mozambique have focused heavily on foreign trade policies and structural adjustment. Basic policy changes in Mozambique are aimed at allowing international and domestic markets to play a central role in the economic development of the country. Before independence, trade was directed almost entirely toward the West. After independence, the government favored trade with the former socialist countries, Scandinavian countries, the Netherlands, France, and Italy. Since 1983, relations have improved significantly with the United States of America (USA) which is currently the major food donor.

In Mozambique, agriculture contributes about 45% to the gross national product (GNP). Table 1.2 presents the gross domestic product (GDP) by sectors of development at constant prices.

Table 1.2. Gross Domestic Product by Origin

	----------- billions of Meticais ----------------					
Year	Agricul ture	Industry & Fisher	Construc tion	Transp. & Commn	Commerce & Others	Total
1985	70.7	19.4	6.2	8.8	23.8	129.0
1990	637.0	390.0	225.0	162.4	292.2	1706.7

Source: Comissäo Nacional do Plano, Informaçäo Estatística, 1991.

Table 1.2 shows that agriculture is the major sector of development in Mozambique, followed by industry and fisheries. Agriculture declined as a percentage of total GDP from 1985 to

1990. Agricultural production of the most important export crops such as tea, cashew, sugar cane, cotton, and citrus declined from 1975 to 1985. This decline was due partly to exogenous factors, including a series of climatic disasters, the lack of security in the country side caused by war, the general turmoil in the southern Africa region and the instability of the international economy during the past decade. The data presented in Table 1.3 show the trend of gross domestic product at factor cost from 1985 to 1989.

Table 1.3: Trend of Gross Domestic Product at Factor Cost

	TOTAL (Billions of Meticais)			PER CAPITA (Thousands of Meticais)		
YEAR	Current Prices	Constant Prices 1980 pr.	Real Change (%)	Current Prices	Constant Prices 1980 pr.	Real Change (%)
1985	129.0	53.4	-9.1	9.3	3.9	-11.6
1986	145.7	54.0	1.0	10.3	3.8	- 1.5
1987	465.7	56.5	4.6	32.0	3.9	1.9
1988	787.4	59.6	5.5	52.7	4.0	2.8
1989	1,238.3	62.7	5.3	80.8	4.1	2.5

Source: Comissão Nacional do Plano, Informação Estatística, 1991.

More than 75% of the people are engaged in agriculture, most of these in subsistence farming. The major problems for agricultural development have been unstable policies, lack of capital investment, and excessive central planning from 1975 to 1981 associated with policies oriented to foreign trade. Infrastructure and social overhead costs were neglected; the markets were distorted through a price setting system.

Overvalued currency eroded the comparative advantage of the country for export. Reliance on government agencies and parastatals for production and marketing introduced inefficiencies into the markets.

The government has experienced a budget deficit for several years. This fact can be assigned to investment in the health sector, education, and housing. Health care and education were provided free of charge from 1975 to 1987. In 1988, a process to remove subsidies in the public sector was started. The objective is to reduce the budget deficit, and there is a belief that the economy will improve if the deficit is removed. In 1991, the overall deficit after deduction of grants represented 6.1% of the gross domestic product. Revenues collected by the government have improved since 1988. However, real deficit cuts have been achieved through the increases in grant aid. The government and donors believe that the budget deficit hampers investment and productivity. This is based on the assumption that the cost of capital tends to rise with an increase in deficits.

Trade taxes have increased rapidly since 1987 as the economy started its recovery, and tax management has been overhauled. In October of 1992, higher taxes were set in an attempt to raise revenues. The removal of subsidies is based on the assumptions that interest rates will fall, and the private sector will be stimulated to invest in productive enterprises, which in turn, will increase average income.

However, what has not been taken into consideration is the fact that the majority of the population is living under subsistence conditions, there is no generation of savings, and capital is almost non-existent. The private sector, trying to maximize profits, does not have incentive to invest in public sector improvements such as roads and schools.

The finances of the central government and the current account trends are shown in the Table 1.4 .

Table 1.4 Central Government Finances
(Outturns; Billions Meticais)

	1986	1987	1988	1989	1990	1991
Fiscal Receipts	16	58	110	200	266	380
Income Tax	4	15	29	43	53	79
Indirect Taxes	9	30	59	105	137	177
Trade Taxes	2	10	19	44	65	109
Non-Fiscal Receipts	7	11	21	27	32	67
TOTAL REVENUE	22	69	131	227	298	447
Current Spending	93	149	246	343	457	457
Wages & Salaries	8	15	25	43	65	101
Defence & Security	12	42	58	102	136	178
Parastatal Transfer	14	9	11	12	14	12
Capital Spend	9	68	140	227	350	501
TOTAL EXPENDITURE	52	161	289	473	693	958
Deficit Before						
Grants	-30	-92	-158	-247	-395	-511
Grants	4	38	92	160	226	397
Overall Deficit	-26	-55	-66	-87	-169	-114
Financing						
Foreign	6	33	53	82	169	128
Domestic	20	19	13	5	0	-13
Discrepancy		2				

Source: Comissão Nacional do Plano, Informação Estatística; Plano Económico e Social, 1991.

The Farming Systems in Mozambique

Mozambique has three agroecological regions: the southern agroecological region is represented by Xai-Xai in this study, the central agroecological region represented by Beira-Buzi, and the northern agroecological region, represented by Monapo in Nampula Province.

The southern agroecological region is dry, with annual rainfall between 400 mm and 600 mm per year. Sandy soils are dominant, with flat lands of open savannas. The average annual temperature is 22°C, which is highest at 40°C in January and lowest at 16°C in June. The major crops in this region are maize, rice, peanut, cassava, beans, citrus, cashew, coconut, and cowpea. Livestock including goats and rabbits are a part of farming systems.

The central region has annual rainfall between 800 mm and 1,400 mm. Soils vary from medium sandy-clay soils to heavy red-sandy soils. The characteristic landscape is a plateau 1,000 meters above sea level. The vegetation is characterized by open tropical forest. The average annual temperature is 24 °C, the highest is 42 °C in January, and the lowest temperature is 16 °C in June. The dominant crops are rice, maize, cassava, peanut, citrus, pearl millet, and sorghum. Livestock is less abundant compared to the southern region of the country. However, production of goats and rabbits are predominant.

The northern part of the country is more humid compared to both the south and central region of the country. The annual rainfall varies from 1,200 to 2,000 mm, and the evapotranspiration values range from 1,300 to 1,700 mm per year. The altitude of this region varies from 400 meters to 1,250 meters above the sea level. The average temperature is 26 °C with a maximum of 42 °C in January and minimum of 19 in June. The most abundant crops are cassava, sorghum, pearl millet, maize, cotton, tea, coconut, and cashew. Livestock is more scarce compared to the rest of the country. Farming systems in all three regions are mainly rainfed agrosystems.

Farming systems in the central agroecological zone include agroforestry type of farming, where slash and burn are dominant. The households use fallow periods of three to five years. In the northern part of the country, like in the center, the use of agroforestry systems is prevalent but with shorter fallow of periods up to three years, and the slash and burn method is not dominant.

Cotton is the major cash crop in the northern part of the country (Monapo) while in Xai-Xai the major cash crop is rice.

Problem Statement

Farmers in Mozambique produce under a high degree of risk and uncertainty. They have low yields and their production barely meets subsistence requirements. Increased farm

production is seen as an important goal for securing food supplies (MOA 1992).

The government, in attempting to motivate farmers to produce more with improved agricultural techniques, provides extension services based on what is perceived to be feasible for farmers. The designed techniques do not take into account household constraints and behavior of household farmers. As a consequence, these recommended techniques are often ignored. There also is a lack of effective agricultural policies directed to motivating farmers to increase production and land productivity.

The institutionalized markets are oriented to export commodities and prices do not reflect local scarcity. Markets for subsistence commodities are not institutionalized and not adequate in remote rural areas.

On the production side, uncertainties are associated with irregular patterns of rainfall, crop diseases, pests, and high storage losses. Farmers respond to climatic events by modifying their production practices. In Monapo, some farmers utilize fertilizer on cotton after the planting period. When rainfall is low or nonexistent, they do not fertilize. This is good agronomic technique because it allows for sequential adaptation of practices in adjustment to early climatic risk.

In Xai-Xai, there is an increase in soil acidity followed by changes in properties of soils. The amount of lime needed to increase soil Ph to neutral is greatly increased as soils

became highly acid. Some areas of Xai-Xai are alfisols and over years of improper irrigation, they are becoming extremely weathered, evolving to oxysols with a decline in soil fertility, increase in soil Ph, and decrease in cationic exchange. Near to the shores of the Indian Ocean, soils are saline due to irrigation of fields when the torrent of Limpopo river is low and admits water from the ocean.

In summary, the major research problems are

1. that farmers in Mozambique are allocatively efficient in use of the available scarce resources, but, policy makers call for a different resource allocation from what the farmers currently use because policy makers view the farmers as inefficient producers;

2. farmers produce under a high degree of risk and uncertainty, they have low yields and production barely meets their subsistence requirements;

3. most farmers use traditional techniques despite the recommendations to use new varieties, new techniques and enterprises that have provided high yields in experimental trials;

4. the pattern of behavior of farmers is not well understood by policy makers;

5. there is a lack of effective agricultural policies directed to household farmers that could motivate them to increase production and land productivity;

6. Prices do not reflect scarcity, and the transaction costs are very high in the rural areas.

Research Objectives

The general research objective is to evaluate farm enterprises in Mozambique in order to identify the major constraints to production.

In conditions of high risk and uncertainty, farmers tend to allocate scarce resources first to those enterprises which guarantee subsistence and food security in the household, and then to those enterprises which generate income. Once food security is assured, the allocation of scarce resources by households is a function of marginal net returns between farm and nonfarm activities. It is important to check if this framework adequately describes farmers' behavior in Mozambique.

Farmers tend to adopt technologies which have low variability in yields and low market risk. The removal of subsidies on imported agricultural inputs, due to the introduction of the structural adjustment program in Mozambique, will reduce the adoption rate of new technologies. This is an assumption that needs to be evaluated with farmers in Mozambique.

The specific objectives are to develop a mathematical programming model for evaluation of the effects of constraints

on family farms under risk and uncertainty in Mozambique, and use the model to analyze the

1. allocation of the scarce resources in the household;

2. decision-making process of the farmers and their strategies for food security; and

3. management of risk by the farmers;

Overview of Dissertation

Chapter 2 presents the importance of agricultural modeling, reviews agricultural modeling around the world and presents the reasons for agricultural modeling in Mozambique. Chapter 3 presents the structure of the time series used to generate indicators of risk, the cross section survey on farm households in Xai-Xai, and the secondary data collected in Mozambique to complement the survey information. The farming systems and agricultural techniques used by the farmers in Xai-Xai are discussed and compared with those of the rest of the country. Food security strategies are summarized and a brief debate on structural adjustment program is included to frame the conditions under which the model will be applied. Chapter 4 is intended to introduce the conceptual framework, model specifications, and estimation of parameters to be used in the empirical model. Chapter 5 presents the components of the farm household model and its implementation. Price policies, exchange rate policies, and subsidy policies in agriculture are simulated and results presented. Chapter 6

presents the results of the study, allocative efficiency under uncertainty, and discusses the implications of the findings on agricultural development in Mozambique. Chapter 7 presents the summary and conclusions.

CHAPTER 2
LITERATURE REVIEW

Introduction

In Mozambique there is a lack of research on agricultural modeling and some policy makers are not favorable to development of models for agricultural systems. There have been criticisms on the part of policy makers that mathematical programming methods and models have not been successful in many African countries (Pitel 1990). They argue that those programs and models do not address the complexities of African agriculture and that they are very expensive (Mucavele 1985). Policy makers have not yet been psychologically prepared to use models as tools for agricultural managements and policy evaluation.

This study recognizes that application of mathematical methods and computation techniques in the management of agriculture require changes in the thinking of people, especially in Mozambique. The socialist economic system, based on state and collective ownership of the means of production, is no longer adopted in the country. Households allocate their resources based on their objectives and constraints (Mucavele 1989).The review of literature presented is intended to provide a summary of recent studies around the

world based on mathematical programming and simulations which have been successful. It is also intended to give an overview of multiplicity of problems that can be addressed in developing countries like Mozambique.

The Importance of Agricultural Models

Agriculture is a complex productive sector which requires a good understanding of its components to be managed successfully. It is a very dynamic sector changing over time. There is no unique and permanent policy that can stabilize the production systems and eliminate entirely the risk and uncertainty in agriculture. Farm modeling offers an opportunity to design and evaluate agricultural systems without disturbing the productive systems.

Farm household models if well defined and characterized, can provide a basis for examining the most binding constraints, and the effects of alternative policies on the well-being of farm households. Such models also provide a basis for studying the "spillover" effects of government policies on other segments of the rural population. They can capture both consumption and production behavior of farmers, and are a tool for examining the effects of pricing policy on marketed surplus, foreign exchange earnings, and budget revenues.

In Mozambique there is a lack of an effective delivery system to provide inputs for crop production at an acceptable

price at the right time, as well as outlets for production surpluses. Therefore, populations in the rural areas have to produce their own foodstuffs using locally available resources, and adopting technologies which are appropriate to the production constraints faced. Most proposed policies overlook this fact forcing disruptions of production.

The literature shows that early mathematical programming models were related to agricultural decision problems. For instance Freund (1956) modelled agricultural risk on production and prices. Pachico (1980) analyzed factors that affect the suitability of efficiency analysis for the assessment of the rationality of resource management in the agricultural sector of low income countries, particularly in the case of traditional peasant farmers. He studied the two components of overall economic efficiency: allocative efficiency and technical efficiency. He concluded that efficiency analyses are important as indicators of resource use. However, when farmers face high degree of risk and uncertainty, the indicators of efficiency must be complemented by a close analysis of productive systems. Mathematical programming models in agriculture are one of the best tools for monitoring the data collection and evaluation of factors affecting agriculture.

Singh (et al. 1986) stated three important reasons for agricultural household modelling. The first one is that agricultural household models capture the relationships

between household production and consumption in a theoretically consistent manner. Ideally such models should enable the analysts to examine the consequences of policy interventions. The second reason for farm household modelling is to analyze the secondary effects of government policies on segments of the rural populations. The third reason is the need to evaluate the performance of the agricultural sector from a multisectoral perspective since agriculture is an important source of revenues for the public budget and foreign exchange.

Lele (1991) found that although many general reports have been written about Africa's economic problems, there are few detailed country-by-country analysis of agricultural problems. She states also that agriculture is the lifeblood of Sub-Saharan Africa because it is the source of employment, income, exports, savings, government revenues, and raw materials for industry. These findings support the suggestion for farm household modelling specially in Sub-Sahara Africa. Agricultural modelling is one alternative way to systematize micro level data collection and to provide detailed information about agriculture.

Systematic modelling of agriculture will provide basic information needed to fill the gap of information in most developing countries. Literature on long-term economic growth analysis point out that agriculture plays a crucial role in structural transformation during the early stages of

development. Several studies (Singh et al. 1986) state that agricultural productivity must be raised and small farmers must contribute to the economic growth. It is clearly evident in the literature that a sustained economic growth can be achieved only if resources and needs are balanced at micro and macro levels. All those findings stress the need for information to monitor agriculture development and allocate resources for sustainable development of the economy. Agricultural modelling provides a mean to collect, systematize, and evaluate information.

Overview of Agricultural Models

Numerous studies and agricultural models have been developed around the world. Several areas of agriculture have been modelled. Gwinn et al. (1992) developed a multiperiod quadratic programming model to derive risk-efficient growth plans and financial structures for a representative cash grain (maize and soybean) farm in the USA under a broader set of sources of risk than had been considered previously and over various levels of risk aversion. The results indicated that farm size, asset structure, and debt level changed significantly with risk-aversion levels and were consistent with empirical observations. The results further indicated investment and financial structures that could prove useful in determining safe and manageable levels of farm financial leverage in the future.

Veeman (1982) used the concept of economic surplus to assess the transfer and social cost effects of the national supply management programs for poultry products. He concluded that different estimating methods and assumptions lead to considerable differences in the social cost estimates. Nonetheless, short-run losses in allocative efficiency were relatively minor compared to the transfer effects. However, the potential long-run losses in efficiency were substantial.

Stefanou and Saxena (1988) using the generalized dual theory, applied a non-frontier profit function model to evaluating allocative efficiency which allows for training (human capital) variables to directly influence the efficiency level. Baron (1982) found that most analyses of allocative efficiency under different forms of agricultural tenure such as share tenancy, fixed cash tenancy, and owner cultivation, employ single-product models of production. These models show that risk sharing encourages share tenants to produce as much as risk-averse owner-operators and cash tenants. However, when risk and risk aversion are introduced into multiproduct linear programming models, relative allocative efficiency under share tenancy may decline (Baron 1982). The result depends on the relative production costs and the relative risk premiums of the different products.

Modelling the farm, using data envelopment analysis (DEA) in a multiproduction scenario, policy simulation may produce a cohesive expected microeconomic analysis of the farm

household. For instance, an empirical evidence, based on estimated equations of up to 10 irrigated crops for six US Bureau of Reclamation (BuRec) production regions in USA, demonstrated that economic analysis of BuRec water supply policy should consider welfare effects in commodity markets in addition to the allocative efficiency of surface water resources (Moore and Negri 1992).

Nonparametric measurement of allocative efficiency, technical efficiency, and economic efficiency dominated the early years of 1990s methodology in production economics (Moore and Negri 1992). The literature presents few empirical studies such as water use in Pakistan (Chaudhry et al. 1990). Pakistan's canal system occurs at three levels: at the water source (river or reservoir); among the major and minor delivery channels (distributaries); and among individual farms, according to the rotation along the watercourse. In order to account for losses in the water course so as to achieve an approximately equal water supply per acre, a modification of the standard "warabandi practice" was introduced (Chaudhry et al. 1990). For each watercourse, a sample of delivery losses was adjusted in accordance with the measurement so as to approximate equal water per unit of land. This proposed allocation mechanism was labelled 'warabandi by quality'. The allocative efficiency measure employed was net economic returns to water for a representative watercourse situation. Equity was assessed as the ratio of tail-end to

head-end net income. Net returns to water were estimated for various scenarios by a model of farmer choices regarding cropping patterns and irrigation practices. Results demonstrated a substantial inequity of income per unit land as a consequence of the neglect of delivery losses in the warabandi system. On equity and allocative efficiency grounds, and because indirect impacts could lead to improved economic efficiency, the analysis is seen to provide evidence in support of modifying Pakistan's warabandi system of water distribution.

Some agriculture models emphasize more the input use instead of output such as the input characteristic model (ICM). The indexes of performance are expressed in terms of input use. The (ICM) was expanded by Wilson and Prezler (1992) to account for technical coefficient uncertainty. The model is used to analyze effects of price and quality on competition in the UK wheat import market. Results were used to identify critical quality characteristics and impacts of technical coefficient uncertainty on import demand. The expected values for most characteristics of US wheat have greater variances than those of Canadian wheat. Results show that both the characteristics' level and variance are important in determining import market shares.

Chen et al. (1990) developed a computer simulated model of cotton harvesting and handling systems to study the interactive effects of the number of harvesters, harvester

capacity, number of boll buggies, number of trailers, weather uncertainties, farm size, area for each maturity group and initial harvest date on total yields and net return. They tested harvest policies and weather uncertainty.

The empirical findings in India (Mythili 1992) confirm that risk is a significant factor preventing farmers from diverting a greater area to peanuts production. If smallholder are responsive to average prices, they are even more responsive to price variability and, more generally, to changes in the degree of uncertainty in their environment.

Boussard (1993) studied the impact of structural adjustment on smallholder farmers, and he concluded that smallholder farmers' development requires institutional innovations aimed at reducing uncertainty due to structural adjustment programs. This could represent a new dimension in structural adjustment programs and policies. There is a need for further research based on household models on the microeconomic side and on computable general equilibrium models on the macroeconomic side.

In Latin America, the geopolitical and macroeconomic context of agriculture has changed considerably since 1985, specially in Colombia (Carreno et al. 1992). Farmers must be prepared to face changes and modernize agriculture. Current challenges include information technology, biotechnology and new means of communication. Encouraging prospects are threatened by management of the stabilization program and by

uncertainty surrounding the intensity and duration of adjustment periods. Modernization presents many new challenges: concern for the environment, overcoming violence, the spreading of democracy and political participation, and the restructuring of agriculture. Revaluation of the Colombian peso, following massive inflows of foreign exchange, is a major threat to the agricultural sector (Carreno et al. 1992). The likely future path of Colombian development is unclear as the development model has changed: biotechnology is replacing the Green Revolution. Sustainability and agricultural development are moving to the forefront: agricultural development is being reoriented. Farming in the Andean zone and on inter-Andean land is becoming more important.

The thrust of agricultural policy in New Zealand since 1984 has been to remove the state from the decision-making environment and let the market work (Johnson 1991). Many collective arrangements for spreading risk were also discontinued in the name of efficiency and nonintervention. Few new arrangements have been introduced to take their place. A study by Johnson (1991) on micro policy initiatives indicated that risk management efficiency probably has been enhanced. The discounting scheme has had good risk management properties though these were not the main objective of the scheme. The "LandCorp" proposals were against leasees' interests in spreading risk but were probably more efficient from the point of view of resource use distortions. The

adverse climatic event proposals were efficient if the individual was the best judge of his own survival mechanisms, though inefficient in preventing a market for risk sharing to develop. Johnson concluded that this was an evolving area of research and policy, and that new arrangements may yet be put in place to reach an appropriate balance between individual and collective risk sharing arrangements.

In Zambia, beans are the most important relish crop in the farming systems. Leaves and dried beans are major food sources for home consumption, and dried beans have a commercial value in the system. Given this dual role, it was expected that increasing bean yields would improve family nutrition as well as economic returns to capital and labor invested. However, low levels of production had been recorded over the years due to the use of local bean varieties, low fertility, and inadequate pest control (Bezuneh 1992). As a result, on-farm research on beans was carried out for four years to identify bean varieties and management strategies that would result in higher yields and economic returns. The outcomes of the four years' on-farm research were analyzed using stochastic dominance efficiency criteria in order to determine the most risk-efficient production management strategies. The results indicated that the Brazilian bean variety Carioca, when used in combination with fertilizer and insecticide, performed best for traditional and small-scale, highly risk-averse farmers in the Serenje District. The

implication was that agricultural extension recommendation should consider risk and uncertainty factors as well as agrotechnique factors.

In Ethiopia, results of a study on risk taking behavior of smallholder farmers suggested that producers in the Central Highlands exhibited slight to moderate, as opposed to extreme, risk averse behavior (Kebede 1992). Income, farm size, education, relatives and experience reduced risk-taking behavior in an area where there were opportunities to diversify sources of income. On the other hand, income, farm size, education and relatives increased risk-taking behavior in an area where farming was the only source of income. Furthermore, the study concluded that risk taking behavior, measured in relative terms, affects adoption of new agricultural technologies, and it was found that improvements in the educational level of producers and other infrastructures greatly increased adoption of new production technologies.

In a highly uncertain environment, diversification can minimize production risks, increase agricultural productivity, and maintain or improve the stability of farm incomes. This is because diversification of cropping systems creates an environment in which farmers have several crop choices, from varieties which are tolerant to diseases, to varieties which are resistant to pests. If pests become adapted to a particular variety, farmers can switch to an alternative crop

and minimize the losses. A common problem is the limited flexibility of agricultural systems in adjusting to economic, political, and technological change, thereby constraining the ability of farmers to adjust to shifting opportunities to maximize their benefits and minimize risk and uncertainty (Barghouti et al. 1992).

Modeling can help to look at the problem of externalities before going on to examine government policies to correct for externalities. Simulation using a programming model can be used to identify expected impacts on public or collective good characteristics associated with household valuation under risk and uncertainty, and policy formulation.

Reasons for Agricultural Modeling in Mozambique

Policy formulation, especially in Mozambique, requires information about production, consumption, trade, and the behavior of producers and consumers. Such information is not available. Institutions are not sufficiently developed to collect and analyze production and consumption data. Production and consumption parameters are not known by policy makers, and cannot be estimated using econometric techniques. The cost of collecting data and keeping government statistics is very high. Therefore, Mozambique relies on a general census to obtain micro and macro indicators for planning and policy formulation.

In searching for sustainable development, government may interfere in economic processes affecting household production systems and conservation of living resources. The government intervention includes improvements in economic efficiency of household production, income distribution, risk, and sustainability of production systems. Many recommended strategies for household production policies and conservation including the World Conservation Strategy (WCS), rely heavily on public intervention and participation of international public bodies (World Bank 1988). While the draft update of the WCS still calls for government intervention, it places much greater emphasis on the use of economic mechanisms and incentives rather than direct intervention by government. Models of farm household can assist government by generating the expected outcomes from a new policy.

Simulation models are approximations of existing production and consumption conditions. They are concerned with the major constraints of the system, allocation of resources, and the objective functions of the systems. Even with incomplete data, it may be possible to simulate scenarios and study the effects of a particular decision or policy. The results of the scenarios can be used for monitoring purposes as well as for calibration of models for future uses. Simulation models in Mozambique provide a convenient framework for incorporating economic welfare and policy aspects. They also provide important aspects of the desired economic

features associated with social parameters. This implies that a decision can be evaluated ex-ante and mistakes can be minimized in policy formulation. Simulation models can incorporate more complex features, such as stochasticity. In the past scientists were forced to make simplifying assumptions so that the resulting model was analytically tractable. With advancements of computation and software, it is possible to develop more complex programs that take into consideration aspects previously left out.

In Mozambique, 61% of the population is illiterate and infrastructure in rural areas does not exist to allow the flow of information and technology. Most of farming systems cannot be diagnosed. Currently, rapid appraisal missions are the most viable tools of data collection. Based on those rapid appraisals, programming models of farm households can be developed to replace the lack of detailed data for econometric analysis. Using these programming models, policies can be simulated to evaluate ex-ante their effects. Furthermore, the effort of building models will bring information for structured data collection and development of institutions such as the Ministry of Agriculture, and the Eduardo Mondlane University.

CHAPTER 3
HOUSEHOLD SURVEYS, RISK MANAGEMENT, AND POLICIES

Introduction: Time Series Data

Data on households in Xai-Xai were collected in two separate but related surveys. The first survey is time series cross-sectional data and the second survey is a cross-sectional sample household information on family composition, production, consumption, and marketing of agricultural products. Before presentation of results of the second survey, it is important to describe the enterprises included in the time series as well as the selection of households for this study.

The time series data collected in Xai-Xai included the zones of Chicumbane, Poyombo, Chiconela, and Chongoene from 1980 to 1990. Several institutions were involved in gathering data including the Departamento de Produção e Protecção Vegetal da Faculdade de Agronomia e Engenharia Florestal, Direcção Distrital de Agricultura in Xai-Xai, Direcção Provincial de Agricultura in Gaza, Serviços Provinciais de Planeamento Físico de Gaza, agricultural cooperatives of Xai-Xai, ISCO the Italian non-government organization for cooperatives, Unidade de Direcção Agrária (UDA) of Xai-Xai, AGRICOM the parastatal for agricultural marketing, Direcção

Provincial de Comércio, Casa Agrária de Poyombo, Casa Agrária de Chiconela, and Empresa Estatal Agrária do Baixo Limpopo.

The Xai-Xai region presents a complex and dynamic farming system which makes time series data recording difficult. The most prevailing consociations in the region are maize-peanuts (MZN), maize-peanuts-squash (MNS), maize-cowpea (MZW), maize-beans (MZB), maize-cowpea-sorghum (MWB), maize-cowpea-millet (MWL), peanuts-maize-beans (NZB), peanuts-cassava (NCA), peanuts-sorghum (NUS), peanuts-millet (NUL), cassava-maize-peanuts (CZN), cassava-peanuts (CAN), cassava-maize (CAZ), cassava-maize-beans (CZB), cassava-maize-cowpea (CZW), and cassava-millet (CAL).

The term consociation refers to a multiple cropping system where two or more crops are grown simultaneously or planted in small intervals of time with no distinct row arrangement. Consociation is opposed to sole cropping. However, consociation as described in this study can be considered relay intercropping (Francis 1986) because two or more crops are grown simultaneously during part of the life cycle of each. The second (third) crop is planted after the first (second) crop has reached its productive stage of growth but before it is ready for harvest.

Sole cropping, as defined by Francis (1986) based on Andrews and Kassam definitions of 1976 is the term used to describe a system where one crop variety is grown alone in pure stand at normal density. It is synonymous with solid

planting and opposite of consociation (intercropping). The major sole crops in Mozambique are rice (RIC), peanuts (NUT), cabbage (CAB), lettuce (LET), tomatoes (TOM), and onions (ONI).

In 1980, at the Eduardo Mondlane University, the first approach was established to collect data of consociation systems. A study was started to develop a recording system of farm household input-output data including farming system characteristics (Mucavele 1983). Approximately 613 farm households were registered during the rapid appraisal and 250 farm households were randomly selected for study. The consociations characterizing the farming systems of Xai-Xai were registered during a rapid appraisal. The purpose was to understand the production systems in the region and to promote a system of production cooperatives which was believed to provide conditions for improvement of labor and land productivities.

Because of the farming systems' dynamics in Xai-Xai, climate changes, and war, most households migrated and the cooperatives disintegrated. In 1991, only 196 farm households were still farming in the region. In 1992, only 110 farm households were possible to include in the survey.

During the eleven years of observations, only seven enterprises have complete input-output records for the 110 farm households, namely MZN, MZW, NUT, NZB, CAS, CAZ, and RIC. These consociations likely represent a strategy used by the

farmers of Xai-Xai to minimize climatic and market risk. The ratio of land use varies from one consociation to another, from one farmer to another, and sometimes from one year to another. Based on observations during the survey and previous studies (Mucavele 1985), the estimates of average land ratio use per crop in the consociation for the eleven years are presented in the Table 3.1.

Table 3.1. Estimates of Average Land Ratio Use per Crop in the Prevailing Consociations in Xai-Xai, 1992

Crop	Type of Consociation						
	MZN	MZW	NUT	NZB	CAS	CAZ	RIC
	----------Proportion of Land-----------						
Maize	0.6	0.6	0.0	0.4	0.0	0.6	0.0
Peanuts	0.4	0.0	1.0	0.3	0.0	0.0	0.0
Cowpea	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Beans	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Cassava	0.0	0.0	0.0	0.0	1.0	0.4	0.0
Rice	0.0	0.0	0.0	0.0	0.0	0.0	1.0

Source: Mucavele, F.G., Estimates Based on 1985 and 1992 Surveys in Xai-Xai, 1994

Records are grouped into inputs and outputs per cropping system. The major inputs recorded are land, labor, cash expenses, fertilizer, and machinery. Output data are recorded by enterprise where numbers 1, 2, and 3 represent first, second, or third crop in the consociation, i.e. MZN1 is the output of maize in the consociation maize-peanuts and NZB3 is the output of beans in the consociation peanuts-maize-beans. In the case of sole crops, the numbers are omitted. The time series records for outputs are MZN1, MZN2, MZW1, MZW2, NUT, NZB1, NZB2, NZB3, CAS, CAZ1, CAZ2, and RIC.

The amounts of inputs used per household are recorded for the seven major consociations. They cannot be allocated to individual crops because the inputs are used by the entire set of crops in the consociation. Land is measured in hectares per year and constitutes the normalizing input because all other inputs are expressed in per hectare base. Table 3.2 presents the average size of farms in Xai-Xai from crop seasons 1980 to 1990.

Table 3.2. Average Farm Size in Xai-Xai from 1980 to 1990. (n=110 Farm Households)

Year	Mean	Standard Deviation	Maximum	Minimum
	------------- Hectares ------------			
1980	3.749	1.036	7.273	1.576
1981	3.280	1.108	7.136	1.084
1982	4.023	1.537	9.401	1.344
1983	3.701	1.071	6.894	1.890
1984	3.790	1.105	7.420	2.184
1985	4.415	1.283	8.569	2.470
1986	4.135	1.268	7.662	1.894
1987	3.974	1.543	9.421	1.451
1988	3.404	1.032	6.615	1.495
1989	3.542	1.172	8.282	1.392
1990	3.983	1.404	10.96	2.144

Source: Mucavele, F.G., Estimates from Time Series 1980-1990, 1994.

Labor is recorded in person-days per cropping system and type of animals produced in the farm household. A person-day is defined as the time corresponding to 10 hours of work in the farm including round trip travel time between the house and the farm. Labor is classified in two categories by gender and age: female and male labor, and adult and child labor respectively. This input is likely the major constraint of

the farming systems in Xai-Xai. It seems that the farmers in this region of the country maximize labor productivity through consociation and they minimizing the variance of yields by diversifying the types of consociation. Table 3.3 presents the average labor available per household from crop season 1980 to 1990.

Table 3.3. Average Labor Available per Households in Xai-Xai from 1980 to 1990. (n=110 Farm Households)

Person-days	Average	Standard Deviation	Maximum	Minimum
Male Adults	1	1.392	6	0
Female Adults	4	1.905	10	1
Male Children	1	0.250	4	0
Female Children	2	0.645	7	0
Total Number	8	2.355	15	2
Total Adults	5	1.762	9	2

Source: Mucavele, F.G., Estimates from Time Series 1980-1990, 1994.

Cash expenses refer to the money used to buy fertilizer, pesticides, seed, and to pay machinery or draft power for crop production per consociation or sole crop. They are measured per farm household in thousands of meticais (c$mt) also known as "contos de meticais" in Portuguese. In Xai-Xai, fertilizer is mostly used for production of rice, peanuts, and sometimes for production of maize and peanuts in maize-peanuts consociations.

Machines (tractors) are only used for land preparation and transportation of inputs and outputs from farm to market or homestead. The unit of measurement used for machinery is

hour. Records for animal draft power are available for the period from 1980 to 1984, after which data are discontinued and not accurate. Table 3.4 presents the average use of fertilizer and machinery in Xai-Xai from 1980 to 1990 per household.

Table 3.4. Average Fertilizer, Machinery, and Cash Used per Household in Xai-Xai from 1980 to 1990. (n=110 Farm Households)

Inputs	Average	Standard Deviation	Maximum	Minimum
Fertilizer(Kg/ha)	150	92	620.0	0
Machinery(hours)	4.2	1.4	9.0	0
Cash(X 1,000 MT)	79.1	25.8	237.5	0

Source: Mucavele, F.G., Estimates from Time Series 1980-1990, 1994.

Average crop yields of production from 1980 to 1990 are summarized in Table 3.5 per cropping system per household.

Table 3.5. Average Crop Yields per Cropping Systems per Household in Xai-Xai from 1980 to 1990. (n=110 Households)

Cropping Systems	Crop	Mean	Standard Deviation	Maximum	Minimum
		----- tons per hectare -------			
MZN	Maize	0.671	0.269	2.533	0.184
MZN	Peanut	0.531	0.289	2.520	0.046
MZW	Maize	0.685	0.354	1.568	0.100
MZW	Cowpea	0.319	0.227	1.052	0.010
NUT	Peanut	0.714	0.361	1.901	0.025
NZB	Peanut	0.531	0.260	1.785	0.037
NZB	Maize	0.587	0.283	3.289	0.075
NZB	Beans	0.616	0.443	2.656	0.032
CAZ	Cassava	2.070	1.912	8.370	0.670
CAZ	Maize	0.496	0.423	2.691	0.130
CAS	Cassava	3.233	1.922	6.166	0.950
RIC	Rice	0.523	0.478	3.100	0.045

Source: Mucavele, F.G., Estimates from Time Series 1980-1990, 1994.

The Cross-Sectional the Survey

The general objectives of the cross-sectional survey were to obtain primary information on family composition, production, consumption, and marketing of agricultural products by the households, and to collect secondary data to evaluate the agricultural sector in Mozambique.

The specific objectives were to:

1. determine the basic characteristics of farm households in Xai-Xai in Province of Gaza, Beira-Búzi in Province of Sofala, and Monapo in the Province of Nampula in Mozambique;

2. generate estimates of technical coefficients of production, household consumption, and resource availabilities to incorporate into a model for farm household evaluation in Mozambique;

3. evaluate the farming systems and determine their basic constraints.

4. assess resource allocation between farm and non-farm enterprises.

5. evaluate the major sources of household income.

6. collect basic secondary data for model preparation and policy analysis.

The information collected in Beira-Búzi and Monapo were intended to make comparative analysis about the farming systems and characteristics of agricultural production in the center and north of Mozambique.

The Structure of Survey

The survey consisted of a questionnaire with five sections. The first section was to identify the basic characteristics of households. The second section was designed to gather information about the farming systems employed by the producers and basic constraints of production. The third section was to obtain data on resource allocation between farm and non-farm enterprises of the household, the fourth section was to collect information on sources of household income, and the last section was designed to obtain information on household consumption.

The questionnaire was written in Portuguese and then translated into Changana, Sena, Ngoni, and Makua which are the languages spoken in the three regions where the surveys were conducted. Three teams of enumerators were formed and trained in summer of 1991. Each team consisted of five enumerators who spoke the local language. Samples were prepared during the fall of 1991 and interviews were conducted from May to August of 1992.

All interviews were conducted at a time established by the household. The head of household led the conversation with participation of the members of the family. Two female enumerators were included to interview women who headed households.

The survey was complemented by records based on observation of production systems, debates with farmers,

technicians, researchers and extensionists. Written documents were collected from the Ministry of Agriculture, Ministry of Commerce, and Eduardo Mondlane University for better understanding of agricultural policies in the country.

Sampling Methods

The rapid household appraisal approach was used to collect data. The base sample was selected randomly in 1980 comprising 250 farm households out of 613 registered by the Serviços de Planeamento Físico de Gaza. In 1992 only 110 farm households were still farming in the region of Xai-Xai and they were included in the survey. To obtain information on the rest of the country, 50 farm households were randomly selected in each of the regions of Beira-Buzi and Monapo. The complete survey included 210 households. To complement the sample, 15 local extension agents were interviewed, 5 in each region.

Fifteen individuals were prepared as enumerators, five for each location. Most of them participated in the agricultural surveys of 1980 and 1984. The estimates from the survey and time series are used as parameters for farm household modeling.

The codification was done in two phases: pre-code and final-code. Pre-code consisted of ex-ante codification of expected responses with open-ended answers to collect as much information as possible. The final-code was based on the pre-

code adjusted to all collected responses to the questionnaire given by the households during the survey. Household income surveys done by the department of statistics served as secondary data for comparison.

Results of the Cross-Sectional Survey

The results of the cross-sectional survey in Xai-Xai indicate that the major objectives of households are assurance of food security and optimization of net incomes from labor and agricultural activities. Farmers seek to develop mixed production strategies that guarantee food for consumption as well as necessary income to purchase manufactured goods. Table 3.6 shows the ranking of their major household objectives.

Table 3.6. Ranking of Major Objectives of Households by the Farmers In Xai-Xai, 1992.

Objective	Percents
Food Security	87.5
Education	5.0
Health and Clothing	3.4
Farm Investment	2.8
Off-farm Investment	1.1
Others	0.2
TOTAL	100.0

When farmers were asked to name their objectives, they provided a list of household goals and desires which they felt to be the most important. This list indirectly explains why farmers allocate their scarce resources to agricultural production. As long as their basic needs in food remains

unsatisfied, they will not be concerned about other goals. Table 3.7 presents the percentage of total repondents reporting each objective.

Table 3.7. Major Objectives of Households In Xai-Xai, 1992. (n=110 Households)

Objective	Frequency (%)
Food Security	96.0
Education	80.0
Health and Clothing	47.0
Farm Investment	38.5
Off-farm Investment	22.7
Others	6.5

During the survey, farmers presented their preferred crops which are listed in Table 3.8.

Table 3.8. List of Preferred Crops in Xai-Xai, 1992 (n=110 Households)

Crops	Frequency (%)
Maize	100.0
Cassava	100.0
Peanuts	100.0
Cowpea	88.2
Beans	71.9
Rice	68.4
Sweet-potato	66.1
Pumpkins	51.5
Sorghum	46.7
Millet	44.4
Cabbage	40.3
Tomato	39.0
Onion	32.7
Potato	26.8
Others	10.2

Farm households in Xai-Xai region are more concerned with production of maize, peanuts, and cassava which are the staple foods. These crops are part of the cropping systems developed

to minimize the risk associated with climatic variations, pests, and diseases. Table 3.9 summarizes the cropping systems ranked from most preferred to the least preferred.

Table 3.9. Preferred Consociations of Crops in Xai-Xai, 1992 (n=110 Households)

Type of Consociation	Frequency (%)
Maize-peanuts-beans	33.7
Maize-peanuts	30.0
Cassava-maize	22.4
Maize-cowpea	11.6
Cassava-peanuts	2.3

The major problems faced by households in Xai-Xai (besides war) are drought, famine, lack of credit, lack of hospitals and schools. The result of the cross-sectional survey are reported in Table 3.10.

Table 3.10. Major Problems Faced by Households in Xai-Xai, 1992. (n=110 Households)

Type of Problem	Frequency (%)
Drought	100.0
Famine	96.5
Lack of Credit	75.0
Lack of Hospitals	45.7
Lack of Schools	42.8

Food needs increase substantially during the hungry season from late November to early March. Even though, households also have some recurrent needs, such as clothing and processed food that is not produced on the farm. Some households near the river produce rice as a cash crop.

Observations about farming systems and discussions with farmers revealed that the farming systems in Xai-Xai are very complex. They involve household decisions interfaced with outside decisions made by members of the household not living in the rural farm household. Decision-making in the household is a multi-stage process in which the members of the household identify the major climatic constraints, food needs, spiritual needs, resources available in the household and other factors of production that can be acquired through relatives and social environment.

It was concluded from the cross-section survey and debates with farmers that production decisions are based on common objectives of the household members. Production Unit choices (PUC) are analyzed one by one and preferred units are selected depending on weather and resources available. In this study, PUC are defined as production enterprises such as cropping systems, animal production systems developed and adapted in the region. PUC are combinations of inputs-outputs associated with techniques, institutions and cultural practices. Climatic factors such as rainfall and temperature are the determinants of the cropping system to be adopted. The household objective function will determine the PUC to be pursued. Based on the survey results, a typical farming system of Xai-Xai is diagrammed in figure 3.1.

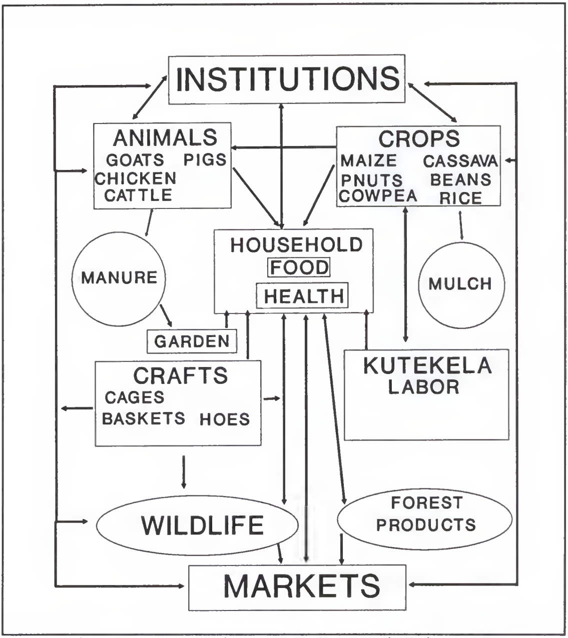

Figure 3.1. Farming Systems of Xai-Xai, 1994.

To understand the farming systems in Xai-Xai, meetings with farmers were organized to discuss the major consociations and intercroppings in the area. Subsequent discussions considered the existing techniques of crop production in Xai-Xai and flexible forms of input combinations which satisfy the risk-efficiency criteria. Discussions with policy makers and observation of practiced cropping systems helped to understand reasons why farmers prefer some types of consociations instead of monocrops. Then, using the information obtained, production unit choices were estimated by forming sets of inputs related to levels of maximum outputs achievable which satisfy quasi-concavity and monotonicity. The objective of estimating production unit choices was to analyze the input use by farmers and establish comparisons among them to identify perceived indicators of performance.

Measures of performance to address intercropping, consociation, and relay cropping systems, are not developed enough in the area of agricultural economics to address properly the problems of production efficiency. In this study, the derived production unit choices are used as a reference point for estimating labor technical coefficients given the existing conditions in Xai-Xai.

The production unit choices vary according to the type of year (bad, normal, or good) in terms of temperature and rainfall pattern. A bad year in Xai-Xai corresponds to a year where rainfall is scarce, usually less than 600 mm of

precipitation. The first rainfall may come in late November or the beginning of December and lasts for four months. It is common that a bad year is made worse by a high incidence of plagues and diseases. Farmers grow crops according to the amount of precipitation from July to September, and depending on the period in which the first rainfall is verified. In Table 3.11 the preferred rank is shown, where the first intercropping will be the most preferred for the very bad year,i.e., maize-cowpea intercropping is the most preferred if first rainfall comes in December. If the first rainfall appears in late October and beginning of November, peanut-maize-beans intercropping is preferred.

A normal year has precipitation between 600 to 1000 mm of rainfall. The normal rainfall period extends from September to February. The sequence of production unit choices in the Table 3.11 for the normal year category represents the rank of preferred intercropping reported by the majority of farmers from an "excellent normal year" to a "poor normal year". In a normal year, some farmers tend to be indifferent to the rank presented.

A good year is defined as the year in which the precipitation is greater that 1000 mm. The rainfall period may extend from September to March. Usually there is a low incidence of plagues and diseases. The pattern of crops will depend on household objectives and demands from the city market.

Estimated production unit choices based on discussions, debates, and observations of farming systems in Xai-Xai are shown in Table 3.11.

Table 3.11 Estimated Input-Output Production Unit Choices (PUC) per Hectare for Farm Households in Xai-Xai, 1992.

PUC	Labor (p.days)	Ferti-lizer (tons)	Machi-nery (hrs)	Cash (c$mt)	Total	Crop1	crop2	crop3
					----Output	in tons----		
				BAD YEAR				
MZW	55	0.00	0.0	0.0	0.80	0.48	0.32	-
CAN	75	0.00	0.0	0.0	1.30	0.80	0.50	-
CAZ	75	0.00	0.0	0.0	1.50	0.90	0.60	-
MZN	55	0.00	0.0	0.0	1.00	0.60	0.40	-
NZB	90	0.00	0.0	0.0	1.00	0.28	0.44	0.28
				NORMAL YEAR				
NZB	55	0.00	3.6	0.0	1.50	0.43	0.64	0.43
MZN	50	0.00	3.6	0.0	1.25	0.75	0.50	-
MZW	40	0.00	0.0	0.0	1.00	0.60	0.40	-
CAZ	45	0.00	3.6	0.0	1.75	1.50	0.70	-
CAN	70	0.00	3.6	0.0	1.50	0.94	0.56	-
				VERY GOOD YEAR				
NZB	75	0.50	3.6	75.0	2.00	0.57	0.86	0.57
MZN	55	0.00	3.6	50.0	1.50	0.90	0.60	-
CAZ	60	0.25	3.6	50.0	2.50	1.50	1.00	-
CAN	55	0.00	3.6	75.0	2.60	1.65	0.95	-
MZW	55	0.00	3.6	0.0	1.30	0.78	0.52	-

Where: MZW is intercropping of maize and cowpea,
MZN is intercropping of maize and peanut,
NZB is intercropping of peanut, maize, and beans,
CAN is intercropping of cassava and peanut, and
CAZ is intercropping of cassava and maize.

The difference in pattern of crops will be a function of the household objectives and preferences. Households in Xai-Xai make decisions in a holistic manner, and they use indicators of food needs as performance measures. The

probability of failure is minimized by a complex diversification of activities and enterprises. All activities around the households are oriented to provide food and some cash to acquire manufactured goods in a most efficient way. The farming systems of Xai-Xai are risk reduction systems which enhance and combine several elements of the environment with existing institutions to assure food security in the household.

The farmers in Xai-Xai classify their production systems based on soils, topography, and water resources. They recognize the habitat diversity, and they perceive it as spectrum of potential possibilities for household improvement in agricultural production. It is a complex framework that should be evaluated when allocative efficiency and overall efficiency are estimated. In Xai-Xai there are two types of systems which are well-defined among farmers. The first one is "machongo", which is a system of lowland with peat, usually wet for most of the time in the year. It is adequate for vegetable production. The second type of systems is called "mananga", a classification which refers to sandy soil with low organic matter content, usually located in a open savanna with a shortage of water. The Xai-Xai region and Chongoene zone have few machongos along the Limpopo river while mananga can be found in Nhapfuine and Cavelene zones. The households generally have some fields in mananga for the production of maize, peanuts, sorghum, millet, and cowpea. In those fields,

they use green fertilization and those who have cattle use manure fertilization of soils. A typical mananga soil management in Chongoene zone is a fallow system of two years of maize with peanuts and pumpkins followed by one year of cowpea and cassava, and then two fallow years. The households use machongos for the production of rice, vegetables and also maize. These two categories are part of the classification commonly used and they are associated with local agricultural techniques.

The common crop rotation is maize after peanuts and cowpea, and cassava with peanuts after maize and sorghum with minor adjustments in plant density. Farmers in Chongoene, along the Xai-Xai district have followed this practice for decades without any application of fertilizers. Fallow is also a common practice in Xai-Xai when the soils gets low in nutrients. However, in recent years, fallowing has been limited considerably by the increasing pressure of population on land. Figure 3.2 presents the most important crops in Mozambique organized by cropping activities from September to August. The crop calendar is an indicator of the common periods of land preparation, planting and harvesting in the south of Mozambique.

According to the survey results, cereals in Xai-Xai occupy 57.8% of the cultivated area of the farm households. Maize is the major cereal crop while sorghum and millet are the minor cereal crops.

CROP	SEPT	OCTO	NOVE	DECE	JANU	FEBR	MARC	APRI	MAY	JUNE	JULY	AUGU
Maize	▲	*	*	*	*		☺	☺	☺		▲	▲
Peanuts	▲ *	▲ *	*	*		☺	☺	☺		▲	▲	▲
Cowpea		▲	▲	▲	*	*	* ☺	☺	☺	☺		
Cassava	▲ ☺ *	▲ *	*	*	*		☺	☺	☺	▲ ☺	▲ ☺	▲ ☺
Beans				▲	▲ *	*		☺	☺			
Rice	▲	▲	▲	▲	*	*			☺	☺		
Cotton			▲	▲	*	*				☺	☺	
Sorghum			▲	▲		*	*		☺	☺		
Sweet Potato			▲	▲	*	*	*	☺	☺	☺		
Vegetables				▲ *	▲ * ☺	▲ *	▲ * ☺	* ☺	* ☺	* ☺	☺	

Figure 3.2. Crop Calendar of Rainfed Farming Systems of Xai-Xai

▲ Land preparation
* Planting
☺ Harvest

Cassava accounts for 21.9% of the total cultivated area, peanuts 10.1%, and the rest of the household cultivated area is cropped by cowpea, sorghum rice, and beans. The crop distribution in Xai-Xai for the entire sample of farm households is shown in Table 3.12.

Table 3.12. Crop Area Distribution
in Sample of Farm Households in Xai-Xai, 1992

Principal Crops	Xai-Xai Farming Region		Average Cropped Area
	Area (ha)	Percent	Per Household (ha)
Maize	291.50	56.26	2.65
Cassava	113.30	21.87	1.03
Peanuts	52.80	10.10	0.48
Cowpea	25.30	4.88	0.23
Beans	16.50	3.18	0.15
Vegetable	11.00	2.12	0.10
Rice & Cereals	7.70	1.59	0.07
Total	517.40	100.00	4.71

Mixed cropping and intercropping is an important characteristic of the existing farming systems in Xai-Xai. Cowpea and beans are the major second crops in the farm households. According to the survey results, farmers prefer mixed crops because peanuts, cowpea, and maize are more susceptible to insects and diseases when grown in pure stands. Also there is a saving in labor required for weeding. Peanuts and cowpea fix nitrogen, a which contributes to increased yields of other crops.

Maize is grown by every household in Xai-Xai with an average of one to three fields per household. Farmers choose to grow maize on land closest to the water, where land is

generally of better quality in terms of soil fertility. It is also a common practice to augment the fertility of land by adding organic waste material to the fields. Peanuts are of economic importance as a cash crop, in part to pay hired labor in Xai-Xai. Table 3.13 presents the yields of the major crops in Xai-Xai.

Table 3.13 Yields of the Major Crops of Farm Households in Xai-Xai, 1992

Crops and Their Association	Average Yields for All Fields(tons/ha)
Maize in Association:	
Maize (main)	0.975
Peanuts	0.350
Cowpea	0.200
Cassava	1.350
Beans	0.050
Cassava in Association:	
Cassava (main)	3.500
Peanuts	0.610
Cowpea	0.045
Beans	0.110
Peanuts in Association:	
Peanuts (main)	1.050
Maize	0.635
Cowpea	0.125
Cassava	1.320
Beans	0.375

Yields are calculated on a per hectare basis which consisted of determining the total production of each crop in the cropping system and then dividing by the total area cultivated for the crop. It also includes produce consumed by the household, the produce sold and offered to relatives and friends living in the city.

Differences in yield among farmers reflect conditions of rainfall, soil fertility, management practices, and the overall resource endowments. They also indicate the institutions governing a particular household, for instance, it is believed in Xai-Xai that the success of a crop season is not only based on practical knowledge, but also depends on satisfaction of family spirits. This suggests that improvement of yields requires institutional development along with introduction of new technologies aimed to reduce risk and increase productivity by changing the types of intercropping.

Estimates of average labor supply per household per day in Xai-Xai are presented in Table 3.14.

Table 3.14. Estimates of Average Labor Available per Household per Day in Xai-Xai, 1992

	Person-Days
Male Adults	1
Female Adults	4
Male Children	1
Female Children	2
Average Size of Household	8
Average Available Adult Labor	5

The cross-sectional survey indicates that on average, a farm household has 5 person-days of adult labor available per day for work. In the sample, the largest household had 13 members and the smallest was composed by one male. The largest number of children in the sample was 7. Females are 75% of the total members of household. Table 3.15 presents the division of labor in Xai-Xai.

Table 3.15 Labor Division in Xai-Xai, 1992
(n=110 Households)

Type of Labor	Activity	Frequency (%)
Adult Female	Farming	93.5
Adult Male	Farming	65.0
Male Children	Farming	27.3
Female Children	Farming	45.7
Adult Women	Household Activities	87.6
Adult Men	Household Activities	45.4
Male Children	Household Activities	67.4
Female Children	Household Activities	87.9
Adult Women	Herding	1.0
Adult Men	Herding	63.9
Male Children	Herding	75.3
Female Children	Herding	0.0
Adult Women	Mining	0.0
Adult Men	Mining	26.2
Male Children	Mining	0.0
Female Children	Mining	0.0
Adult Women	Traditional Doctor	7.0
Adult Men	Traditional Doctor	3.9
Male Children	Traditional Doctor	0.0
Female Children	Traditional Doctor	0.0
Adult Women	Student	2.0
Adult Men	Student	13.9
Male Children	Student	85.0
Female Children	Student	55.5

Agricultural production systems in Xai-Xai are highly labor intensive. Technology is based on land and labor input use with a minimal or no use of purchased inputs. The supply of labor in the household plays a crucial role in determining the quantity of land to cultivate, and the timeliness of the various operations necessary for crop and animal production. One dominant characteristic of the agricultural production systems in Xai-Xai is the role of women in managing crop fields. For maize, cassava and peanuts, women control the

production, sales, and consumption. Sixty two percent of the households interviewed during the surveys depended on those crops for food security. Those households have the man working seasonally in the city or in mining. It is another way houaeholds assure extra income for the family.

Table 3.16 presents the average units of animals produced per household per year.

Table 3.16. Average Units of Animals Produced per Year Per Household in Xai-Xai, 1992. (n=110 Farm Households)

Type of Animal	Average Units	Standard Deviation	Maximum	Minimum
Chickens	6	3	14	2
Ducks	2	1	5	0
Pigs	2	1	7	0
Rabbits	3	1	10	1
Goats	4	2	15	0
Cattle	1	0.65	4	0

Animal production in Xai-Xai is mainly for household consumption, for instance chickens, pigs, and rabbits. Cattle are used for draft power to intensify crop production, and as an additional source of income and savings. Cattle are used as the closest approximation to currency, lease-lending agreements among farmers, and the object of ratifying marriage. One of the goals of having cattle in Xai-Xai is social prestige: the more animals a man (or household) can boast the more important he (the household) is. Goats provide meat, milk, and they are the most desired reward for loyal services.

Household Food Security and Strategies of Risk Management

The term "food security" in this study means the ability of the household (or a region) to assure, on a long-term basis, that its food systems provide the entire family with timely, reliable, and nutritionally adequate food. The World Bank (1986), defined food security as the access by the all members of the household at all times to enough food for an active and healthy life.

To improve household food security, households follow different strategies. Among them, they use risk-reducing inputs, production diversification, holding reserves, development of communal information systems and mutual help insurance schemes. The general strategy of households' food security in Xai-Xai is the variation of intercropping systems, mixes of farm household production of staples, and production of cash crops associated with goats and livestock. Usually during hungry periods the households sell livestock for food or they rely on non-farm activities to generate income to buy food. Seasonal and long term migration by one or more members of the family members is the common practice in most households. During the period from October to February, off-farm labor in Xai-Xai has low opportunity cost. Families where males are in majority, occupy a large part of household members' time in seasonal labor in the city of Xai-Xai or in Maputo.

There is some dependency of the households on the market for food because of the high variability of yields and diversification of household income is a strategy of household food security. However, it is not clear if the households place greater reliance on the market than in food production. In Xai-Xai, market purchases accounted for 43 percent of the cereals consumption in the household (Survey, 1992). Even though, the market is not reliable. There is a lack of food for purchase which limits the household ability to meet the food security requirements based on the market. This is one of the reasons why households are unlikely to put more resources into the production of cash crops if they cannot be assured of reliable supply of food to purchase with their cash earnings.

Food security is one dimension of livelihood security. Chambers (1991) defined livelihood as adequate stocks and flows of food and cash to meet basic needs. Households in Xai-Xai are poor and they need to balance their competing needs for asset preservation, food supply in the present and in the future, generation of income, and leisure and spiritual satisfaction. In addition to those strategies of crop production, household will hold their assets to the point they achieve chronic hunger. They do not respond arbitrarily to variability of food supply, they develop self-insurance system of strategies to minimize risks. It was verified in Xai-Xai that there is a wide range of those strategies. It is not

possible to find one pattern for all farm households. But in general, households put their major cash crops and staples at recurrent risk and develop self-insurance coping strategies such as planting small plots of the main farm and according to the rainfall pattern they decide what kind of crop consociation should follow. It might happen that rain comes late, then the household decide that wife (or wives) will plant millet, and cassava, the males will seek off-farm work in the city, or they might decide to sell goats or existing cattle to acquire food depending on the level of available staples in the household.

Chickens and goats are liquid assets in Xai-Xai while cattle is a productive asset. During good harvest years, households buy goats and sometimes rabbits as a form of savings and self-insurance. During famine periods (or years) they sell chickens first, then rabbits, and finally goats. Cattle are rarely sold because they are used for animal draft in the production systems, and represent capital assets.

The Impact of Structural Adjustment Programs

Farmers in Mozambique are impacted by recent changes in policies and direction of the economy. After independence, the economy was centralized and all decisions concerning agriculture were decided at the government level. Policies were directed at creation of large state farms, highly mechanized with intensive use of chemicals. Prices were fixed

by the state. Cooperatives were believed to be the major agricultural structure to develop farm household production. Since 1987 the direction of economy changed. Large farms and state farms are no longer conceived as sources of development. Farm households and private farms are at the top of policies. Markets are believed to drive the economy in the future, placing structural adjustment programs in position to be the key tool for correction of distortions in the economy.

It was observed during the survey that farmers still are not used to the idea of a free price system. They still believe that government sets the price of all commodities, even though some products are liberalized. They are not sure if the free market system will work. Inflation associated with continuous devaluations of currency in the last five years left farmers confused. They do not understand the kind of economy being established in the country. Information is not accessible for poor and illiterate farmers.

One of the policies of the structural adjustment program is the removal of subsidies. One example of such a policy is the removal of subsidies for fertilizer. In Xai-Xai, only farmers growing rice were affected. Increases in the price of fertilizer was not compensated for by an increase in price and yield of rice. It is not clear if production of rice declined or increased after introduction of the structural adjustment program. It seems that after the introduction of the economic and social rehabilitation program farmers do not rely on

markets to satisfy their food requirements. A major proportion of their crop sales is used to purchase clothes, sugar, education for children and health. Figure 3.17 presents the average cash expenditure per household.

Table 3.17. Average Household Cash Expenditures in Xai-Xai, 1992. (n=110 Households)

Item	Mean	Standard Deviation	Maximum	Minimum
	x1,000 $MT		---x 1,000 $MT--	
Fish	15.000	3.750	19.150	0.000
Beef	35.250	7.433	75.650	5.900
Milk	3.860	0.978	4.100	2.420
Oil	35.965	12.200	83.130	7.100
Drinks	98.311	15.244	137.310	12.650
Sugar	115.805	66.875	189.540	55.210
Cloths	260.900	77.860	278.450	156.420
Petrol	37.500	10.310	86.221	5.800
Health	55.320	32.860	135.806	2.000
Education	98.450	42.800	122.080	7.500
Total	756.361	268.135	1,856.095	322.122

Farmers allocate labor and capital first to production of maize, peanuts, and cassava which are the major food staples. Once food is assured, labor is allocated to non-farm activities to generate income to purchase non-agricultural goods and services.

Credit and investments are lacking in Mozambique due in part to low saving rates in the global economy. Household savings tend to be modest, partly because of the critical importance of spending for current consumption. On the other hand, there is a lack of high-payoff investments that reward people for foregoing consumption to invest in the future.

Financial markets and institutions are not sufficiently developed to stimulate savings. Improvement of farm households require investment in technology and education. Under the structural adjustment program, financial institutions in Mozambique, as a policy, are supposed to give priority to agricultural enterprise development, generally within broad government guidelines. Banks are expected to channel some of their funds through programs of rural credit. Those programs charge lower interest rates on loans to food crop production, 17 percent compared to the commercial rate of 25 percent.

Overvalued exchange rates in the period before 1987 resulted in large imports. Those imports choked domestic production and induced a reallocation of resources toward non-tradables by the households. Due to protection of Mozambican agriculture, the prices for non-tradable agricultural inputs and consumer wage goods increased. The overvalued exchange rate also made it difficult for agriculture and industries to compete in the international markets. The expansion of the money supply to meet budget shortfalls created inflation problems. There was "excessive" consumption of tradables compared with the level of production and investment, excessive mechanization in agriculture, substitution of labor by capital in state farms, and unsustainable balance of payment deficits. With fixed nominal foreign exchange rates, the real exchange rate rose.

Devaluation was introduced to achieve exchange parity. Due to the need for foreign currency, most of the cash crops such as cotton, citrus, cashew nuts, banana, and pineapple are exported. The country produces less food than is needed to satisfy domestic requirements. Even so, it exports its produce to acquire foreign currency to gain access to purchased imported inputs and technology. Farmers are affected by this situation. The benefits from exports are not directly felt by the farmers. In Xai-Xai, the structural adjustment program has not produced the desired features it was expected to produce.

Conclusions from Household Survey and Data Collection

The time series data and cross-sectional survey show that the major objectives of households are to assure food Security and to optimize net incomes from labor and agricultural activities. Their major problems are drought, famine, lack of credit, lack of hospitals and schools.

Households in Xai-Xai make decisions in a holistic manner, and they use indicators of food needs as performance measures. The probability of failure is minimized by a complex diversification of activities and enterprises. The prevailing staple food crops in Xai-Xai, are maize, peanuts, cassava, cowpea, beans, and rice. The prevailing cropping systems are maize-peanuts (MZN), maize-cowpea (MZW), peanuts-maize-beans (NZB), and cassava-maize (CAZ). Peanuts, cassava,

and maize depending on the climatic conditions, availability of inputs, can be grown as sole crops. Basic animal production is confined to chickens, rabbits, goats, pigs, and ducks. Some households have cattle which they use for draft power.

The major constraints to crop production are shortage of labor, capital, and lack of agricultural infrastructures to facilitate input delivery and marketing of production. The cross-sectional survey indicates that on average, a farm household has 5 person-days of adult labor available per day for work. Differences in family composition explain the difference in farm size. Large families tend to cultivate larger areas and have lower yields per hectare.

The decision-making by the households in Xai-Xai is a multi-stage process. They use production unit choices to rank alternative production cropping systems given levels of risk and uncertainty. They also use those production unit choices as performance measures for their activities. For crops such as maize, cassava and peanuts, women entirely control the production, sales, and consumption in the household. Sixty-two percent of the households in Xai-Xai depended on those crops for food security.

CHAPTER 4
ANALYTICAL FRAMEWORK

Theory of Household Production Models

Households are the main form of economic organization in developing countries. Their study demands careful recognition of relationships among household members, which partially determine the household objective function. Every household has developed ways of conducting activities connected with food. How food is acquired, which foods are selected for consumption, how are prepared, stored, and served, who eats them, with whom, when, and how.

The basic theory of household production models assumes that households maximize their utility function for any production cycle, and act as perfect competitors in all products and markets (Singh et al. 1986):

$$\begin{gathered} U = U(X_a, X_m, X_l) \\ s.t. \\ P_m X_m = P_a(Q - X_a) - w(L - F) \\ X_l + F = T \\ Q = Q(L, A) \end{gathered} \tag{3.1}$$

where the commodities are an agricultural staple (X_a), a market purchased good (X_m), leisure (X_l), and prices of the

market-purchased commodity (P_m), and staple (P_a). Q is the production of staple by the household, w is the market wage, L is total labor input, and F is family labor input. $Q-X_a$ is the marketed surplus, L-F if positive is hired labor and, if negative is off-farm labor supply. The labor constraint $X_l+F=T$ says that the household cannot allocate more time to leisure, on-farm production, off-farm employment than the total time available to the household.

The three constraints on household behavior can be collapsed into a single constraint. Substituting the production constraint into the cash income constraint for Q, and substituting the time constraint into the cash income constraint for F, yields a single constraint of the form $P_mX_m + P_aX_a + wX_l = Wt + \pi$, where $\pi = P_aQ(L,A) - wL$ and is measure of farm profits (π). In this equation the left-hand side is the total household expenditure on the market-purchased commodities, the household purchase of its own output, and the household purchase of its own time in the form of leisure (Singh et al. 1986). The household problem becomes:

$$\begin{gathered} MAX\ U = U(X_a, X_m, X_l) \\ s.t. \\ P_mX_m + P_aX_a + wX_l = wT + \pi \end{gathered} \tag{3.2}$$

Let Γ be the lagrangean such that:

$$\Gamma = U(X_a, X_m, X_l) - \mu(P_m X_m + P_a X_a + wX_l - wT - \pi) \qquad (3.3)$$

where μ is the shadow price of household utility. The first order conditions are:

$$\begin{aligned}
\frac{\delta\Gamma}{\delta U_{xa}} &= U_{xa} - \mu P_a = 0 \\
\frac{\delta\Gamma}{\delta U_{xm}} &= U_{xm} - \mu P_m = 0 \\
\frac{\delta\Gamma}{\delta U_{xl}} &= U_{xl} - \mu P_l = 0 \\
\frac{\delta\Gamma}{\delta U_{\mu}} &= P_m X_m + P_a X_a + wX_l - wT - \pi = 0
\end{aligned} \qquad (3.4)$$

Simplifying the system of equations yields

$$\begin{gathered}
\mu = \frac{U_{xa}}{P_a} = \frac{U_{xm}}{P_m} = \frac{U_{xl}}{P_l} \\
\wedge \\
P_m X_m + P_a X_a + wX_l = wT - \pi
\end{gathered} \qquad (3.5)$$

The first condition indicates that marginal utility at the optimal allocation of resources should be equal to the ratio of marginal utility of the staple commodity and its price, equal to the ratio of marginal utility of market-purchased good and its price, equal to the ratio between marginal utility of leisure and its price. These results indicate that the value of income associated with profit maximization behavior depends on prices and resources available. Changes in factors influencing production will change income and consumption (Singh et al. 1986). In the

theory of household models, consumption behavior is not independent of production behavior.

Conceptual Framework

The households modeled in this study are consumed to make rational production decisions which are multi-dimensional and sequential. They are both producers and consumers of their produce. Their major decisions include what should be produced, what should be consumed, how to manage risk and uncertain outcomes, and because of war, they had to decide where to live in the short term while awaiting improvement in security conditions. Every day, households are faced with decisions concerning food consumption, the quantity and quality of services to purchase, hours of work in farming activities and off-farm as wage earners.

The major sources of income include crop production, animal production, and off-farm income from labor earnings as wage earners. The net output in a specific period will depend on the net input quantities and the endowment of the inputs at the end of the previous period. The allocation of resources is based on expected returns, food security, and agroclimatic conditions.

The model formulation maximizes net household income subject to production technology, food security, and household

resources. The general farm household programming model can be written as to find $X_j \geq 0$ (j=1,....,n) which

$$\begin{gathered} Max\ Z=\Sigma_{j=1}^{n} C_j X_j \\ s.t \\ \Sigma_{j=1}^{n}\ a_{ij} X_j \leq b_i \quad (i=1,....,m) \end{gathered} \tag{4.1}$$

where the X_j represents the decision variables, C_j are the objective function coefficients representing the net returns from production activities, a_{ij} are the technical coefficients, and b_i are the resource endowments available for the household production activities.

Farmers in Xai-Xai use technologies that have uncertain yields resulting from high degree of variability in climatic conditions, diseases, and pests. This variability is expressed by uncertain yields of cropping systems. Crops such as maize, cassava, and peanuts are the major staple crops in food security. They are cultivated in different cropping systems which allow farmers to reduce the probability that yields fall below minimum food requirements. Technical coefficients for those crops are uncertain due to uncertain rainfall, floods, diseases, and pests. Variance and covariances of yields for the different alternative cropping systems are used as measure of risk in this analysis.

The approach used in this study was first developed by Merrill (1965). This approach is a non-linear programming method which incorporates the mean and variance of the

uncertain technical coefficients in the constraint matrix. Given an equation containing uncertain a_{ij}'s one may write the mean of the uncertain constant as $\Sigma_j a_{ij} X_j$ and its variance as $\Sigma_k \Sigma_j X_j X_k \sigma_{ikj}$. The constraint containing uncertain coefficients can be written as (Boisvert and McCarl 1990):

$$\Sigma_j a_{ij} X_j + \Phi \ \Sigma_k \Sigma_j X_j X_k \sigma_{ikj} \leq b_i$$

or, using standard deviations:

$$\Sigma_j a_{ij} X_j + \Phi \ (\Sigma_k \Sigma_j X_j X_k \sigma_{ikj})^{0.5} \leq b_i$$

where a_{ij} is the mean value of the yield coefficient, Φ is the risk aversion coefficient defined exogenously, σ_{ikj} is the variance-covariance of matrix a_{ij}, and $\Sigma_k \Sigma_j X_j X_k$ is the variance of uncertain technical coefficient. Therefore, the complete conceptual framework becomes:

$$\begin{gathered} Max\ Z=\Sigma_{j=1}^{n} C_j X_j \\ s.t \\ \Sigma_{j=1}^{n} a_{ij} X_j + \Phi \ \Sigma_{k=1}^{k} \Sigma_{j=1}^{n} X_j X_k \ \sigma_{ikj} \leq b_i \quad (i=1,\ldots,m) \end{gathered} \tag{4.2}$$

The b_i are the endowments of resources such as land, labor, fertilizer, and machinery available for farm household production; feed and sanitary inputs available for animal production; and the household labor amounts available for off-farm activities.

Merrill's approach has remained virtually unused since its development principally because of its incompatibility with available software (Boisvert and Mccarl 1990). In this study, it is possible to use Merrill's approach because the

algorithm GAMS/MINOS provide capabilities for handling the non-linear constraints.

Model Description

The empirical model is based on the proposition that, given any two distributions with equal means, a risk averter will prefer the distribution with the smallest variance. This is consistent with the expected utility maximization. Decisions can be ranked in terms of the first and second moments of the distribution such as mean and variance.

The empirical model selects the cropping systems to be used by the household and determines the hectares of each cropping system to be planted; it decides the types of animals to be produced and calculates the total units of animals to be produced per specie; it determines the amount of crops and animals to be consumed and to be sold; and it allocates labor for off-farm activities to maximize the household welfare.

The decision variables (X_j) in equation 4.2 represent income generating activities in crop production, animal production and farm income. Seven cropping systems are included in the model, namely MZN, MZW, NUT, NZB, CAZ, CAS, and RIC. Six crops are included in the cropping systems which are maize, cassava, peanuts, beans, cowpea, and rice. Animal production includes chicken, rabbits, goats, pigs, ducks, and cattle. The resource requirements for animal production

depend on the type of animals produced on the farm, the purpose of animal production, and the season of the year.

The coefficient of risk aversion is a subjective measure which varies from household to household. It reflects the behavior of the household in relation to mixed enterprises. The inputs to the model are land, labor, capital (cash), fertilizer, and machinery. Four time periods are defined for allocation of labor. Period 1 includes the months of June, July, and August; period 2 covers September, October, and November; period 3 includes December, January, and February; and period 4 includes March, April, and May.

The technical matrix of the model is comprised of the technical input requirements such as land, labor, fertilizer, machinery, and cash expenses for each cropping system. Besides the technical constraints, minimum food requirements are introduced in the model to represent household food security. Each household has different requirements for food security. There is a level of food crops and animal protein required by the household which is a function of the number of members in the household, and the diet preferences of the household. The coefficients used in this model are minimal subsistence levels, which allow members of the household to perform usual desired normal activities, with desirable health conditions. Cash is needed to purchase services, manufactured consumption goods, and factors of production such as fertilizer, seed, pesticides, and tools.

Using the results of the time series data from 1980 to 1990, and the cross-sectional survey, a medium farm household of 5 hectares, with 8 members is modelled. Labor use and the sequences of cropping systems are simplified to make the model manageable. In the future, it is recommended to develop a multiple sources and timing of risk programming model such as discrete stochastic programming to better address the sequential nature of farming systems in Mozambique, and the type of risk and uncertainty faced by the farmers in the country.

The detailed model is presented by the system of equations 4.3.

$$Max\ Z = -\ \Sigma_{i=1}^{7} C_i X_i - \Sigma_{k=1}^{6} D_k AN_k + \Sigma_{j=1}^{6} P_j S_j + \Sigma_{k=1}^{6} R_k SA_k + \Sigma_{t=1}^{4} Lab_t OWR_t$$

$$s.t$$

$$\Sigma_{i=1}^{7} X_i \ \le \ Land$$

$$\Sigma_{i=1}^{7} Lcrp_{it} X_i + \Sigma_{k=1}^{6} Lanim_{kt} AN_k + Lab_t \le Labor_t \quad for\ t=1,\ldots,4$$

$$\Sigma_{i=1}^{7}\ Fertil_i X_i \ \le \ Fertilizer$$

$$\Sigma_{i=1}^{7} Machin_i X_i \ \le \ Machinery$$

$$\Sigma_{i=1}^{7} Y_{ij} X_i - S_j - \Phi\ \Sigma_{i=1}^{7} \Sigma_{h=1}^{7} X_i X_h \sigma_{ihj} \ \ge \ Mincrop_j \quad for\ j=1,\ldots,6$$

$$AN_k - SA_k \ \ge \ minanimal_k \quad for\ k=1,\ldots,6$$

$$X_i,\ S_j,\ AN_k,\ Lab_t,\ \ge 0 \tag{4.3}$$

Where:

- C_i is per hectare production cost (cash cost) of cropping system i in thousands of meticais per year;

- X_i are hectares planted to cropping system i;

- AN_k are units of animal k produced;

- D_k is production cost per unit of animal k in thousands of meticais;

- AN_k are units of animal type k produced;

- X_k is the number of animal units produced per year;

- P_j is per unit selling price of crop j;

- S_j are sales of crop j in metric tons;

- S_k are sales of animal k;

- R_k is selling price of animal k;

- Lab_t is the off-farm labor in person-days used in time period t for labor income;

- OWR_t is the wage rate of off-farm labor in period t;

- Land is the total land available in hectares;

- $Lcrp_i$ is the labor required per hectare of cropping system i in period t;

- $Lnim_{kt}$ is the labor required per unit of animal k in period t;

- $Labor_t$ is the total labor available in period t;

- Φ is the risk aversion coefficient defined exogenously; when Φ=0, the uncertain crop constraint becomes:

$$\Sigma_{i=1}^{7} Y_{ij} X_i - S_j \geq Mincrop_j \; ;$$

- σ_{ihj} is the covariance of yield of crop j from cropping system i and cropping system h. σ_{ihj} =/= 0 if both cropping system i and cropping system h produce crop j;

- $Fertil_i$ is the required fertilizer per hectare of cropping system i;

- Fertilizer is the total tons of fertilizer available;

- $Machin_i$ is the required hours of machinery per hectare of cropping system i;

- Machinery is the total hours of machinery available;

- Y_{ij} is the yield of crop j from cropping system in tons per hectare;

- $Mincrop_j$ are the minimum requirements of crop j;

- $Minanimal_k$ is the minimum unit requirements of type animal k;

Particularities of the Model

The major feature of this model is the use of consociation systems where the yields of maize, cassava, and peanut are stochastic. Since they are subsistence crops, households want to assure that the total yields of those crops do not fall below the minimum requirements.

The model relates the mean value of uncertain yields with production choices represented by the seven consociations. These consociations are a type of strategy to manage risk and minimize the probability of failure due to uncertain climatic conditions. This model is consistent with profit maximization models given that at the margin, the value of marginal product is greater than the marginal factor cost because of the marginal product is discounted to assure that the variability

of yields does not result in crop production falling below the food security level (Marsh 1991). Without uncertainty due to yield variability and chronic food insecurity, the cropping systems in Xai-Xai would be different from the existing systems.

This model provides a framework to produce planning indicators for agricultural policies and food security. These indicators are needed to derive vulnerability maps of food insecurity suggested by Frankenberger (1993) at the micro level using mathematical programming.

CHAPTER 5
EMPIRICAL IMPLEMENTATION OF THE FARM HOUSEHOLD MODEL

Introduction

The conceptual framework of this model was described in Chapter 4. The model is designed to represent farm households operating under conditions of risk and uncertainty in Xai-Xai, Mozambique. The empirical model is developed using the General Algebraic Modeling System (GAMS). The GAMS solver is a modular in-core non-linear optimization system (MINOS). Because of MINOS, GAMS provides a series of advantages (Brooke et al. 1988) such as:

1. introduction of new methods, or of new implementation of existing methods are possible without requiring changes in existing models. Linear, nonlinear, and mixed integer optimization are accommodated as well as the special cases of simultaneous linear or nonlinear systems;

2. the optimization problem can be expressed independently of the data. This separation of logic and data allows problems to be increased in size without causing an increase in the complexity of the representation;

3. GAMS does not require details in array sizes and scratch storage; and

4. explanatory text can be made part of the definition of all symbols and is reproduced whenever associated values are displayed.

Figure 5.1 presents the components of the model in a schematic form.

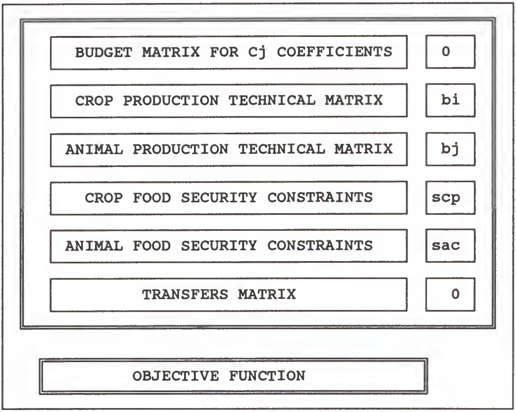

Figure 5.1. Schematic Representation of the Farm Household Model

The empirical model includes seven cropping systems designated by SET I: maize-peanuts (MZNUTS, maize-cowpea (MZCOWS), peanuts (PEANUT), peanut-maize-beans (NTMZBE), cassava (CASAVA), and rice (RICES). There are six crops labeled as SET J: maize (MAIZE), cassava (CASAV), peanuts (PNUTS), beans (BEANS), cowpea (COWPEA), and rice (RRICE). The animal production is represented by six species labeled as

SET K: chickens (CHICKS), rabbits (RABBIT), goats (AGOTS), cattle (ACOWS), pigs (APIGS), and ducks (DUCKS).

Four time periods are established as SET T: period 1 (TIME1) from June to August, period 2 (TIME2) from September to November, period 3 (TIME3) from December to February , and period 4 (TIME) from March to May. The inputs are land (LAND), labor for both crop and animal production (CLABOR and ALABOR), machinery (MACHIN), fertilizer (FERTIL), and capital (CASH) (see Appendix B). The average modeled farm household is assumed to have a total of 8 family members, with a total of two children, 5 females, males and farm of about 5 hectares.

Objective Function

The objective function of the model is to maximize the total net income of the household subject to the available household resources and food security constraints. The coefficients of the technical matrix are uncertain which reflects the variability in crop yields.

The major sources of income included in this model are crop revenues from cropping activities, animal revenues from sales of animals produced in the farm, and labor income from off-farm activities. There might be other sources of income such as gifts and other illegal returns. Those sources of income are not significant in the total household income.

Equation 5.1 summarizes the objective function of the empirical model.

$$
\begin{aligned}
&-\Sigma_{i=1}^{7} X_i * CCost_i + \Sigma_{j=1}^{6} Salec_j * Pcrop_j \\
&-\Sigma_{k=1}^{6} XA_k * ACost_k + \Sigma_{k=1}^{6} salea_k * Panim_k \\
&+\Sigma_{t=1}^{4} LABWF_t * OFWR
\end{aligned}
\tag{5.1}
$$

were: X_i are hectares allocated to cropping system i,

$Ccost_j$ is the cash expenses per hectare of crop j,

$Salec_i$ is total amount of crop i sold,

$Pcrop_j$ is the price per ton of crop j,

XA_k is the number of animals k produced,

$Acost_k$ is the production cost of animal k,

$Panim_k$ is the price of animal k,

$Salea_k$ is number of animals k sold,

$Labwf_t$ is the total amount of off-farm labor,

OFWR is the off-farm wage rate,

Technical Coefficient Matrix and Constraints

The matrix of the technical coefficients represents the agricultural technologies used by the farmers of Xai-Xai to produce crops and animals under risk and uncertainty. Land is the primary factor of crop production. The quantity of land farmed is largely dependent on family labor available for farming activities. The model utilizes a production system characterized by crop consociation, where two or more crops share the same land during some periods of the year. The

proportion of land used per crop varies from farmer to farmer. The land crop ratio is a function of crop physiology, soils, and nutrient requirements of plants in consociation. The average land crop ratio for the seven consociations was estimated and adjusted to one hectare basis. Table 5.1 presents the average land ratio by cropping system in Xai-Xai.

Table 5.1. Average Land Ratio per Cropping System in Xai-Xai, 1992. (n=110 farm households)

Crops	Cropping Systems						
	MZNUTS	MZCOWS	PEANUT	NTMZBE	CASMZ	CASAVA	RICES
	proportion						
MAIZE	0.6	0.6	0	0.4	0.6	0	0
CASAV	0	0	0	0	0.4	1	0
PNUTS	0.4	0	1	0.3	0	0	0
BEANS	0	0	0	0.3	0	0	0
COWPE	0	0.4	0	0	0	0	0
RRICE	0	0	0	0	0	0	1

Source: Mucavele, F.G., farm household survey, 1994.

Labor coefficients are expressed in person-days per hectare of cropping system, and they are shown in the Table 5.2.

Table 5.2. Labor Matrix for Crop production

Periods	Cropping System						
	MZNUTS	MZCOWS	PEANUT	NTMZBE	CASMZ	CASAVA	RICES
	Person-days						
TIME1	20	0	35	25	5	15	0
TIME2	15	15	20	20	20	10	45
TIME3	10	20	10	15	10	20	40
TIME4	0	20	0	10	5	5	25

Source: Mucavele, F.G., farm household survey, 1994.

Labor coefficients represent the total labor needs to carry out all production activities including land preparation, seedling, weeding, irrigation, transportation in the field, and harvest. The labor requirements by cropping system or animal unit are divided into four periods. Table 5.3 presents the technical coefficients of labor requirements for animal production.

Table 5.3. Labor Matrix for Animal Production

Periods	Type of animal					
	CHICKS	RABBIT	AGOTS	ACOWS	APIGS	DUCKS
	Person-days					
TIME1	3.5	7.5	60.0	115.0	10.0	4.5
TIME2	3.5	7.5	45.0	95.0	10.0	4.5
TIME3	3.5	7.5	45.0	95.0	10.0	4.5
TIME4	3.5	7.5	60.0	115.0	10.0	4.5

Source: Mucavele, F.G., farm household survey, 1994.

Where: CHICKS are animal units of chickens; RABBIT are animal units of rabbits; AGOTS are animal units of goats; ACOWS are animal units of cattle; APIGS are animal units of pigs; and DUCKS are animal units of ducks.

Fertilizer is used in peanuts, cassava-maize, and rice production. A rate of 25 , 50, and 250 Kg is used for the three crops respectively. Machinery coefficients are 3.6 hours for maize-peanuts, 5.5 hours for peanuts, 3.6 hours for peanuts-maize-beans, 3.6 hours for cassava-maize, 5.5 hours for cassava, and 6.5 hours for rice.

Yield coefficients per hectare per cropping system are shown in the Table 5.4.

Table 5.4. Matrix of Yield Coefficients for crop production in Xai-Xai, 1992.

Crops	Cropping Systems						
	MZNUTS	MZCOWS	PEANUT	NTMZBE	CASMZ	CASAVA	RICES
	------------ Tons per Hectare ----------------						
MAIZE	0.672	0.568	0	0.587	0.496	0	0
CASAV	0	0	0	0	2.070	3.233	0
PNUTS	0.530	0	0.713	0.531	0	0	0
BEANS	0	0	0	0.616	0	0	0
COWPEA	0	0.319	0	0	0	0	0
RRICE	0	0	0	0	0	0	0.523

Source: Mucavele, F.G., farm household survey, 1994.

Variance and covariance coefficients were calculated from time series. The right hand side (RHS) of the model is the set of resources available. They were estimated in the cross-sectional survey in 1992 (chapter 3). The RHS includes land, labor, fertilizer, machinery, and minimum food requirements. The coefficient of risk aversion was exogenously defined to be equal to 0.1 in the base model.

Implementation of the Model

The first run of the model is the base scenario represents the average farm households of Xai-Xai. Based on the time-series survey, a medium farm household has 8 members of which 5 are adults. Their major objectives are to assure minimum food requirement and to maximizing net incomes subject to technologies and resources available. The coefficients of the model are those already defined. The purpose of the base

run was to check if the model solution was consistent with observed behavior.

The purpose of the second run of the model is to evaluate the effects of risk. Five levels of risk were tested: 0.0, 0.5, 1.0, 1.5, and 2.0. These levels are assumed to represent different degrees of risk aversion among farmers. There are farmers who are neutral with respect to the variability of yields (coefficient 0.0). Some farmers have low degrees of risk-aversion (0.5), and others are highly risk-averse (1.5 or 2.0). Those farmers who are highly risk-averse tend to require low variances of yields because they desire to minimize the probability that yields fall below minimum requirements. Farmers who are less risk-averse, will have low penalties meaning that they will accept some range of variability in yields and therefore have lower risk penalties.

The third scenario was to test the assumption that sole maize crops with high yield variability will not be grown by highly risk-averse farmers. This was done by introducing a new sole cropping system of maize (MAIZZZ).

The fourth run of the model simulates the price policies, exchange rate policies, and subsidy policies. It consists of increasing the price of fertilizer, pesticide, seed, machinery, and the cost of capital. The exchange rate is simulated through increase in price of rice and peanuts.

CHAPTER 6
RESULTS AND DISCUSSION

Results of the Model

The first run of the base model resulted in an objective value of 15,355,280.00 meticais ($MT) which is equivalent to 2,559.21 dollars (US$) per year per household of 8 members. This means that per capita income is 319.90 US$. Table 6.1 presents the crop production solution.

Table 6.1. Results of Crop Production from the First Scenario of the Farm Household Model

Cropping System	Area (Hectares)	crops	Production (Tons)
NTMZBE	0.121	Peanuts	0.064
		Maize	0.071
		Beans	0.750
CASMZ	0.181	Cassava	0.375
		Maize	0.090
CASAVA	2.734	Cassava	8.839
RICES	1.964	Rice	1.027

Crop sales include 9.135 tons of cassava, 1.027 tons of rice, and 0.074 tons of beans. Animal production consist of 8 chickens, 4 rabbits, and 2 goats. All the animals are for household consumption. Allocation of labor to off-farm activities for earnings is 418 person-days of off-farm labor in period 1, 304 person-days in period 2, 271 person-days in

period 3, and 324 person-days in period 4. Land and labor are the major constraints binding the solution of the base run.

These results are consistent with prevailing production cropping systems in Xai-Xai. The solution of the model is similar to the types of consociations used by the farmers. The solution includes 1.027 hectares of rice. Farm households in Xai-Xai generally do not have such large areas of rice. This result reflects variables not currently included in the model, for instance market constraints or land quality constraints. This suggests that in the future, more variables should be included in the model to better address conditions of production marketing and migration of labor. Infrastructure is inadequate to allow flow of produce from the rural areas to the cities. Rice is the major subsistence foodstuff for urban areas like Maputo, and the marketing systems include a high degree of risk associated with transportation, storage, and packaging of produce. Probably the net returns after transaction costs is below the nominal price at the farm gate. Cassava is processed locally and stored to be used during hungry periods. The rural markets for cassava are well developed compared to other crops.

The second scenario evaluates the effects of risk. Five levels of risk were tested. The results indicate that as the risk-aversion coefficient increases, the objective value decreases from 15,354,293 $MT when the risk-aversion coefficient is zero, to 15,306,040 $MT when risk-aversion

coefficient is very high (2.0). For small risk aversion the changes in objective value are very small. For instance a change of risk-aversion coefficient from 0.0 to 0.1 causes only a small change of 987 $MT per year, which is equivalent to 17 cents of a dollar. The small variation of objective value when large variation of risk aversion is introduced is due to the type of cropping system used in Xai-Xai. The variances of consociations are very small and there are no significant differences between highly risk-aversion farmers and low risk-version farmers. Consociations are stable in yields compared to sole and mono cropping systems. The model could be more sensitive to risk aversion if more risky production systems with high yields were included.

There is complementarity between crops in the consociation which allow savings in labor and provide protection for the main crop in case of diseases and plagues. This may be one of the reasons for stability of yields. Given the existing conditions, the farmers of Xai-Xai assure food security by cropping consociations despite of their low yields to achieve stability in production.

Off-farm labor is not changed by the degree of risk-aversion changes. This fact is related to low variances of yields. Farmers adjust the allocation of areas for cropping systems in such a way they still have the same number of person-days for off-farm activities or for labor income. Table 6.2 presents the results of the second scenario.

Table 6.2. Optimal Solutions to the Risk-Aversion Simulation in Second Scenario.

Risk Φ	Cropping System	Area (Hectares)	Animal Production	Units	Off-Farm Labor (Person-Days)	
0.0	NTMZBE	0.121	CHICKS	8	TIME1	417
0.0	CASMZ	0.180	RABBIT	4	TIME2	304
0.0	CASAVA	2.736	AGOTS	2	TIME3	271
0.0	RICES	1.964			TIME4	324
0.5	NTMZBE	0.122	CHICKS	8	TIME1	418
0.5	CASMZ	0.186	RABBIT	4	TIME2	304
0.5	CASAVA	2.730	AGOTS	2	TIME2	271
0.5	RICES	1.963			TIME4	324
1.0	NTMZBE	0.123	CHICKS	8	TIME1	418
1.0	CASMZ	0.193	RABBIT	4	TIME2	304
1.0	CASAVA	2.723	AGOTS	2	TIME3	271
1.0	RICES	1.961			TIME4	324
1.5	NTMZBE	0.124	CHICKS	8	TIME1	418
1.5	CASMZ	0.201	RABBIT	4	TIME2	304
1.5	CASAVA	2.715	AGOTS	2	TIME3	271
1.5	RICES	1.960			TIME4	324
2.0	NTMZBE	0.125	CHICKS	8	TIME1	418
2.0	CASMZ	0.212	RABBIT	4	TIME2	304
2.0	CASAVA	2.706	AGOTS	2	TIME3	271
2.0	RICES	1.958			TIME4	324

Small variances of yields mean that if household becomes more risk-averse, the increase in labor to cultivate a larger area for cropping activities which assure food subsistence will be small. Animal production does not change with increase of risk-aversion or introduction of a maize sole crop.

In the third scenario, the assumption that sole maize crops with high yield variability will not be grown by highly risk-averse farmers is tested by introducing a new sole cropping system of maize named MAIZZZ. The variance-covariance is of sole crop maize with enterprises including maize assumed to be higher (0.5 and 0.75) compared to covariance-variances of crops in consociations included in the basic model. The yield of maize is relatively high compared with the yields of maize grown in consociations such as maize-peanuts, maize-cowpea, and maize-cassava. The yield of sole crop maize is assumed to be 2.0 tons per hectare. The average yield of maize for eleven years in the consociation maize-peanuts is 0.672 tons per hectare, in the maize-cowpea is 0.568 tons per hectare, in the peanuts-maize-beans is 0.587, and in the cassava-maize is 0.496.

Results indicate that without risk aversion (Φ=0), a small plot of 0.045 hectares is allocated for production of maize as sole crop. When risk-aversion is taken into account (Φ>0), sole maize cropping system is not selected for the optimal solution. Table 6.3 presents the results of the third scenario simulation.

Table 6.3. Optimal Solution to the Introduction of Sole Maize Crop in Third Scenario.

Risk Φ	Cropping System	Area (Hectares)	Animal Production	Units	Off-Farm Labor (Person-Days)	
0.0	NTMZBE	0.121	CHICKS	8	TIME1	417
0.0	CASAVA	2.853	RABBIT	4	TIME2	305
0.0	RICES	1.982	AGOTS	2	TIME3	269
0.0	MAIZZZ	0.045			TIME4	323
0.5	NTMZBE	0.121	CHICKS	8	TIME1	418
0.5	CASMZ	0.186	RABBIT	4	TIME2	304
0.5	CASAVA	2.730	AGOTS	2	TIME2	271
0.5	RICES	1.963			TIME4	324
1.0	NTMZBE	0.123	CHICKS	8	TIME1	418
1.0	CASMZ	0.193	RABBIT	4	TIME2	304
1.0	CASAVA	2.723	AGOTS	2	TIME3	271
1.0	RICES	1.961			TIME4	324
1.5	NTMZBE	0.124	CHICKS	8	TIME1	418
1.5	CASMZ	0.201	RABBIT	4	TIME2	304
1.5	CASAVA	2.715	AGOTS	2	TIME3	271
1.5	RICES	1.960			TIME4	324
2.0	NTMZBE	0.125	CHICKS	8	TIME1	418
2.0	CASMZ	0.212	RABBIT	4	TIME2	304
2.0	CASAVA	2.706	AGOTS	2	TIME3	271
2.0	RICES	1.958			TIME4	324

Sole maize crop is not part of solution because increasing risk-aversion, implies an increasing marginal rate of substitution of expected yields for reduced variability. Farmers are willing to forego higher expected yields in return for reduced variability of yields, holding utility constant.

The risk premium would be the amount of yield that make the farmer indifferent between cropping maize as a consociation crop receiving the relatively certain amount and cropping maize as a sole crop and being exposed to increased variability of yields. Risk averse farmers are willing to forego the advantages of high maize yields to avoid uncertainty.

The fourth scenario is a simulation of price changes due to devaluation of currency in Mozambique. Imported foodstuffs such as rice became domestically expensive which can be translated into the change of price from 1,100.00 $MT per Kg to 1,750.00 $MT per Kg. Peanuts are export crops and their price is increased from 2,000.00 $MT to 2,100 $MT per Kg. The results did not change significantly because peanuts are not part of the optimal solutions and rice increases are very small. Increases in prices are not large enough to shift the allocation of resources. However, if the price of rice is increased to 2,000.00 $MT per Kg, more land and labor are allocated to rice. If minimum food requirements are relaxed, peanuts become part of the solution. If fertilizer price is

increased to 2,500.00 $MT per Kg, resources are reallocated to subsistence crops. Cassava becomes the cash crop. Labor and land are the major constraints limiting increases in size of farms.

The results of the fourth scenario are consistent with observed behavior of farmers in Xai-Xai. Data collected during the cross-sectional survey indicate that increases in the prices of fertilizer, pesticides, and fuel from 1987 to 1992 introduced shifts from peanut production to maize and cassava. Some rice producers have also reduced their production. It is not clear, in the case of rice production, what may be the major factor contributing to the decline. However, farmers point out the drought and increases in input prices such as fertilizer and pesticides.

It is important to recognize that markets are distorted and there are several factors which may affect marketing in Mozambique. For those farmers who only buy, and those who buy more produce than they sell, increase in prices will reduce their purchasing power in the short-run. On the other hand, incomes will increase for those farmers who only sell or sell more than they buy. Farmers who do not participate in the market will not be affected by price policies in the short-run. Table 6.5 presents crop sales for the second, third, and fourth scenarios for the different risk-aversion coefficients.

Table 6.4. Optimal Volumes of Crop Sales to the Simulated Scenarios

Risk Φ	Crop	Sales2	Sales3	Sales4
		----------Tons--------------		
0.0	Cassava	9.136	9.143	9.143
0.0	Beans	0.074	0.074	0.074
0.0	Rice	1.027	1.037	1.037
1.0	Cassava	9.116	9.116	9.116
1.0	Beans	0.076	0.076	0.076
1.0	Rice	1.026	1.026	1.026
1.5	Cassava	9.103	9.103	9.103
1.5	Beans	0.076	0.076	0.076
1.5	Rice	1.025	1.026	1.025
2.0	Cassava	9.089	9.089	9.089
2.0	Beans	0.077	0.077	0.077
12.0	Rice	1.024	1.024	1.024

where: sales2 - are tons of produce sold in the second scenario where five levels of risk are evaluated;
sales3 - are tons of produce sold in the third Scenario when high yield sole crop maize is introduced the model;
sales4 - are the tons of produce sold in the fourth scenario when price increses are simulated;

Analysis of Results and Allocative Efficiency Under Risk

The model results are consistent with observed cropping systems in Xai-Xai. The agricultural environment is dynamic, characterized by interaction of environmental conditions, weather, changing demands, and unpredictable policies. A high degree of risk and uncertainty is a consequence of those interactions and lack of means to cope with changes. Farmers will continue to grow consociated crops while risk and uncertainty are prevailing.

Under uncertainty, the criterion of equating the value of marginal product to the factor price, assuming risk neutrality is inappropriate. Introduction of high yield maize as sole crop into the model showed that if risk is not taken into account, the sole crop is a part of solution, but when risk is introduced, the high yields of sole crop maize do not compensate for the variability of yields; and therefore, sole maize crop is not part of solution.

Farmers of Xai-Xai face severe lack of information about prices, markets, and technologies. They face constraints on capital and infrastructures to increase yields and commercialize possible surplus production. Under these conditions, households maximize net returns subject to yield variations, which is directly related to food security. At the optimum allocation of resources, they equate the price of the scarce factors of production compounded by the risk to the marginal yield associated with those inputs.

There is pressure to increase production to cope with increasing population in the country. Structural adjustment programs are introduced with the goal of motivating farmers and the overall economy to develop. Input-intensive technologies are recommended in the hope that they will increase agricultural production. But input-intensive technologies require purchased inputs which increases economic risk for poor farmers. Imperfect access to credit and information about technologies create additional uncertainty. Recommended optimal factor uses are derived by maximizing crop profits using results generated under experimental station conditions. Usually those recommendations ignore agroclimatic variability, capital constraints, and farmers' risk attitudes. Based on these analyses, it is concluded that in Xai-Xai, risk plays an important role.

1. Risk is the major component of existing decisions.

2. Policies or recomendations that ignore risk and farmers' risk preferences are likely not to be successful nor adopted.

3. Policies and technologies that explicitly reduce the risks and uncertainty faced by farmers should be important components of any program to increase production.

Farmers in Xai-Xai have a shortage of improved varieties of maize, peanuts, cassava, cowpea, and millet. Yields of existing varieties cannot be increased sufficiently to assure a sustainable agricultural development. There should be an

integrated approach to develop programs which generate technologies based on local varieties. Those varieties usually are resistant or tolerant to diseases. Agricultural research and extension should be incorporated into a broader strategy to reduce production risks while improving yields.

Given the climatic conditions, infrastructure and existing institutions in Mozambique, farmers are risk efficient in producing foodstuffs. They optimize the use of local resources and limit use of purchased inputs. To improve overall economic efficiency, reduction of transaction costs must be achieved with collective action such as transportation, storage, and marketing of produce. Productivity can be increased by reducing uncertainty in the market system and delivery of commodities, allowing farmers to experiment with new technologies which are more productive and to rely on the market to satisfy the household needs.

CHAPTER 7
SUMMARY AND CONCLUSIONS

Summary

The general objective of this study was to evaluate the farm enterprises in Mozambique in order to identify the major constraints to food production. The results of the survey indicate that the major objectives of farmers in Xai-Xai are to provide food security to their households and to optimize net incomes from labor and agricultural activities. The major production constraints are labor, capital, and rainfall. The production unit choices are based on these factors.

The collected farm household data indicate that farmers in Xai-Xai region are more concerned with the production of maize, peanuts, and cassava which are the staple foods. They grow varieties which have low variability of yields because they are risk-averse. Unfortunately these varieties have low yields which require them to use more land, labor and other resources to satisfy minimum food subsistence. Farmers in Xai-Xai do not adopt new varieties of maize because the yields of these varieties have a high degree of variability and the supply of fertilizers and pesticides is very irregular. The prices of fertilizers and other inputs required by new maize

varieties are not accessible to poor farmers. Therefore, farmers prefer to continue growing traditional varieties.

The specific objectives of this study were to develop a mathematical programming model for evaluation of the effects of constraints on family farms under risk and uncertainty in Mozambique. The empirical model was used to evaluate farm households in Xai-Xai. The model maximizes net returns subject to uncertain yield coefficients, technology, and food security. The results of the basic model provide solutions which are consistent with observed production systems in Xai-Xai. The model solutions included consociations of peanuts-maize-beans, and cassava-maize which the surveys indicated to be the most preferred.

Simulations using the model indicate that as the risk-aversion coefficient increases, the objective value decreases. Large variations of risk-aversion coefficients resulted in small variation of the objective value which is due to the low variances of yields of the cropping system used in Xai-Xai. This confirms that farmers are risk efficient given the highly risky environment in Xai-Xai. This result is consistent with optimizing behavior stated by Marsh and Magnusson (1969) that farmers under uncertainty equate the marginal value product of inputs, for instance land and labor, to their price compounded by a risk premium equal to the marginal yield risk associated with inputs such as labor and land in this study, weighted by the risk preference or marginal rate of substitution.

Risk is the major component of existing decisions in Xai-Xai. Policies or recomendations that ignore risk and farmers' risk preferences are likely not to be successful nor adopted. Policies and technologies that explicitly reduce the risks and uncertainty faced by farmers should be important components of any program to increase production.

Data collected during the cross-sectional survey indicate that increases in the price of fertilizer, pesticides, and fuel from 1987 to 1992 introduced shifts from peanuts production to maize and cassava production systems. Some rice producers reduced their production. It is not clear, in the case of rice production, what may be the major factor contributing to the decline. Some farmers attribute the decline of rice production to drought and increases in input prices of fertilizer and pesticides. Intercropping combined with non-farm labor enterprises are the major strategies used by households to assure minimum food requirements and monetary income.

Price policies are not sufficient to achieve a sustained supply response from a large and growing number of poor households. Price shifts will result primarily changes in crop pattern rather than an overall increase in output. Poor farmers will lose access to inputs and new technologies, and they will tend to increase the area for subsistence crops.

The lack of credit along with the high cost of fertilizers, pesticides, and farm equipment hampers adoption

of new technologies. The shortage of draft animals to pull new equipment limits the possibility of small farmers to adopt new technologies to increase their productivity. Existing technologies do not promote progress. In Xai-Xai new varieties of maize are promoted. They require a different timing in planting, harvest, and labor from the existing practice. The uncertainty of rainfall is relatively high in the southern part of Mozambique which increases the risk associated with adoption of new technologies in Xai-Xai. For new technologies to be adopted, they need to be low in cost without any special incentive or outside assistance.

The farmers of Xai-Xai, based on time series data and the cross-sectional survey, are allocatively risk efficient given the current conditions, but they are not adopting progressive agriculture techniques to cope with the increasing population and changing economy. It is extremely difficult to increase productivity and agricultural production with prevailing constraints.

The general strategy of food security used by the farmers in Xai-Xai is the variation of intercropping systems, mixes of farm household production of staples, and production of cash crops associated with goats and livestock. This strategy is a risk reducing strategy based on variability of yields. Usually during hungry periods the households sell livestock for food or they rely on non-farm activities to generate income to buy food. Seasonal and long term labor migration by

one or more members of the family is the common practice in most households.

Conclusions

Reduction of uncertainty and risk must be one of the goals of policy development in Mozambique. Agricultural risk programming can provide information to decision makers about sources of risk and uncertainty, and the probable behavior of farmers under conditions of a high degree of risk and uncertainty. Given the conditions in Mozambique, it is not necessary to measure individual risk preference to study the effects of a proposed policy. Simulations can give the likely expected impacts of a new policy. The model developed in this study showed that it is sufficient to categorize efficient alternatives such as low, moderate or high aversion to risk and still obtain results that are consistent with reality.

This study suggests the use of existing data on cropping systems, production and distribution of inputs and outputs to generate underlying distributions. With complementary rapid household surveys, basic data can be collected to estimate parameters of technical production, food security, constraints of production systems, and other elements which can help to develop the household production model for agricultural risk modelling.

Programs must be targeted to agriculture at the same time attention is given to health, education, and nutrition. In

the long-run, this approach will reduce overall risk and uncertainty. It requires investment in those sectors to provide development of human and institutional resources in Mozambique. Participation of farmers in the design of agricultural programs depend largely on education. Performance of agriculture in Mozambique depends on farm households development.

Agricultural policies include increases in input prices which may reduce production of export crops such as cotton. As result, stagnation of exports may take place followed by a re-allocation of resources to subsistence foodstuffs. In Mozambique where 80% are farm households, the perceived comparative advantage in agriculture will mean low value of marginal product which can be translated into low net income for households.

The structural adjustment program in Mozambique is expected to reduce the current account and fiscal deficits via the reduction of internal demand. The expected increasing food supply by the structural adjustment program requires effective policies that encourage surplus production. This should be achieved by increase in yields to satisfy food requirements of households after which farmers will produce for market.

Changes in prices through adjustment in exchange rate and trade policies create high levels of inflation and introduce additional uncertainty to agriculture. Reduction in public

expenditures including subsidies in agriculture, education, and health hampers the creation of the necessary conditions for agricultural improvement. There must be a balance between efficiency-oriented policies and policies involving attention to asset distribution, productive and social services, and income transfers through food price stabilization and food for work programs. These programs must be considered complementary rather than competitive.

To promote the progress of farm households, the policies at the macro level must be based on micro foundations such as the need for foodstuffs, education, and health. Policies must be formulated in a holistic manner, where all the productive and consumption systems are taken into account. If this is properly done and farmers understand what is happening, they will be motivated to participate. Formulation of agricultural policies should be based on micro foundations. Programs must be targeted to reduce uncertainties in agriculture. Farmers should be called to participate in designing such programs. Policy makers can assist farmers by avoiding policies that increase risk in agriculture. It must generate policies based on an explicit acknowledgement of the constraints and potentials of farm households.

Wrong policies and programs in the past created the need for macroeconomic adjustments, temporarily diverting attention from the long term issues of productivity, sustainability, and food security of farm households. There must be a balance

between efficiency-oriented policies and policies involving attention to asset distribution, productive and social services, and income transfers through food price stabilization. These programs must be considered complementary rather than competitive.

It is concluded in this study that the extent to which increased risk affects the decision making of farmers depends on producer risk attitudes and abilities to bear risk. Risk-averse farmers make agricultural decisions based on expected yields and prices, and variability of yields and prices. Food security is the major household objective.

Recommended technologies must reflect agroclimatic conditions, labor and capital constraints as well as the attitudes of farmers towards risk. They should be sustainable and compatible with prevailing agricultural systems. Economic viability as applied to farm households should be broadened to include minimum subsistence requirements for the family members.

Agricultural risk modeling using chance constrained models, discrete stochastic programming, and safety-first models are recommended for future agricultural modeling of agriculture in Mozambique. These models incorporate risk, sequential decision-making, allow policy maker to evaluate policies ex-ante, provide a focal point for collecting information and identifying key pieces of information that need to be collected.

APPENDIX A
HOUSEHOLD SURVEY

SUMMARY OF RAPID HOUSEHOLD APPRAISAL

1. INTRODUCTION: OBJECTIVES

The objectives of this rapid household appraisal were to:

1. determine the basic characteristics of the farm households in Mozambique to be incorporated into the programming model for farm household evaluation in Mozambique;

2. evaluate the farming systems and determine their basic constraints;

3. assess resource allocation between farm and non-farm enterprises;

4. evaluate the major sources of household income.

5. collect basic secondary data for model preparation and policy analysis.

2.METHODS

2.1 SAMPLING

Rapid household appraisal approach was used in three provinces of Mozambique. In the south, the survey was done in Xai-Xai, province of Gaza with collaboration of the department of agriculture and ISCO, an Italian organization. In the central part of the country, the survey was was done in Búzi, province of Sofala with collaboration of "Companhia do Búzi",

a sugar cane industry. In the northern part of the country the survey was done in Nampula, with collaboration of the Department of Agriculture and the Food Security Project headed by the Ministry of Agriculture and Michigan State University.

The sample was selected randomly and included 110 households in Xai-Xai, 50 in Beira-Buzi, and 50 in Nampula totaling 210 households. To complement the sample, 15 local extensionist agents were interviewed, 5 in each location.

Fifteen enumerators were prepared to be the interviewers, five for each location. Most of the enumerators proposed to participate have been involved into the past agricultural surveys.

There were two codification systems: pre-code and final-code. Pre-code consisted of codification of responses which allowed open ended answers, and final-code was based on all the answers given by the households. The final data processing was based on the final-code.

Household income surveys done by the department of statistics served as secondary data for contrast.

2.2 Questionnaire.

SECTION I: BASIC CHARACTERISTICS OF HOUSEHOLDS

1. Name of household (optional).
2. Members of household:
    1. females,
    2. males.

3. Occupation of members of the household:

    1. agriculture,
    2. laborer,
    3. household activities,
    4. school,
    5. other activities,

4. Religion.

5. Major problems of the households.

6. Major goals of the households.

SECTION II: FARMING SYSTEMS AND BASIC CONSTRAINTS

1. List of crops.
2. Area of sole crops.
3. Major intercropping and area.
4. Major mixed crops and area.
5. Small animal production (list and number).
6. Livestock production (list and number).
7. Land preparation.
8. Cultivation methods.
9. Major problems in crop production.
10. Major problems in livestock production.
11. Last year/campaign crop production.
12. Last year/campaign livestock production.
13. Major inputs for crop production.
14. Major inputs for livestock production.
15. Time of labor/work in crop production.
16. Time of labor/work in livestock production.

17. Other activities related with farming.

18. Who does farming?

19. Who does livestock?

20. Who does other activities related with farming?

SECTION III: RESOURCE ALLOCATION BETWEEN FARM AND NON-FARM ENTERPRISES OF THE HOUSEHOLD

1. What are the financial resources of the household?
2. How do household allocate financial resources?
3. What are the household "in kind resources"?
4. How do household allocate "in kind resources"?
5. What are other household resources?
6. How those resources are allocated?
7. What was conceived to be "resource" for this household?

SECTION IV: SOURCES OF HOUSEHOLD INCOME

1. Monetary income:
    1. what are the sources?
    2. how much in each source?
2. Agricultural income:
    1. crops,
    2. small animals,
    3. livestock.
3. Labor income:
    1. migrated household member,
    2. others (socio-cultural).

4. What are the major problems to increase income in the household?

SECTION V: HOUSEHOLD CONSUMPTION

1. Major needs of the household from the market.
2. Crops for household and consumption.
3. Animals for household consumption.
4. "In kind" exchange.

APPENDIX B
GAMS BASIC MODEL

```
*     PROGRAMMING MODEL FOR FARM HOUSEHOLD EVALUATION
*                 FILE NAME: FIRMINO8.GMS
*-----------------------------------------------------------
*                   FAMILY COMPOSITION
*-----------------------------------------------------------
SCALAR    MEMB total members of the family    /8/;
SCALAR    CHIL total number of children       /2/;
SCALAR    FEMA total female members           /5/;
SCALAR    MALE total male members             /3/;
*-----------------------------------------------------------
*                 DEFINITION OF INDEXES
*------------------------------------------------------------
SETS I    cropping systems
     / MZNUTS, MZCOWS, PEANUT,NTMZBE, CASMZ,
      CASAVA, RICES /

     J    crops
     /MAIZE, CASAV, PNUTS, BEANS,
      COWPEA, RRICE/

     T    time periods
     /TIME1, TIME2, TIME3, TIME4/

     K    animal production
     /CHICKS, RABBIT, AGOTS, ACOWS,
      APIGS, DUCKS/;

*------------------------------------------------------------
*                   TECHNICAL MATRIX
*------------------------------------------------------------
ALIAS(I,IA);

TABLE LANDR(J,I)   mean land ratio per cropping system
          MZNUTS  MZCOWS PEANUT   NTMZBE CASMZ CASAVA RICES
 MAIZE      0.6     0.6     0       0.4    0.6    0      0
 CASAV      0       0       0       0      0.4    1      0
 PNUTS      0.4     0       1       0.3    0      0      0
 BEANS      0       0       0       0.3    0      0      0
 COWPEA     0       0.4     0       0      0      0      0
 RRICE      0       0       0       0      0      0      1;
*------------------------------------------------------------
```

```
TABLE CLABOR(T,I)    labor requirements in person-days
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA  RICES
 TIME1   20       0     35      25     5     15      0
 TIME2   15      15     20      20    20     10     45
 TIME3   10      20     10      15    10     20     40
 TIME4    0      20      0      10     5      5     25 ;
*-----------------------------------------------------------

TABLE ALABOR(T,K)    labor requirements in person-days
          CHICKS RABBIT AGOTS   ACOWS   APIGS   DUCKS
  TIME1     3.5    7.5   60.0   115.0   10.0     4.5
  TIME2     3.5    7.5   45.0    95.0   10.0     4.5
  TIME3     3.5    7.5   45.0    95.0   10.0     4.5
  TIME4     3.5    7.5   60.0   115.0   10.0     4.5 ;
*-----------------------------------------------------------

TABLE MACHIN(T,I)    machinery use in hours per hectare
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA  RICES
 TIME1   3.6      0     5.5     3.6   3.6  5.5     6.5
 TIME2    0       0      0       0     0    0      1.0
 TIME3    0       0      0       0     0    0       0
 TIME4    0       0      0       0     0    0       0  ;
*-----------------------------------------------------------

TABLE MYIELD(J,I)    per hectare mean crop yields in tons
          MZNUTS  MZCOWS PEANUT   NTMZBE CASMZ CASAVA RICES
 MAIZE    0.672   0.568   0       0.587  0.496  0      0
 CASAV    0       0       0       0      2.070  3.233  0
 PNUTS    0.530   0       0.713   0.531  0      0      0
 BEANS    0       0       0       0.616  0      0      0
 COWPEA   0       0.319   0       0      0      0      0
 RRICE    0       0       0       0      0      0      0.523;

*-----------------------------------------------------------
*                    VARIANCE MATRIX
*-----------------------------------------------------------

TABLE VARMZ(I,IA)    variance-covariance of maize
          MZNUTS   MZCOWS  PEANUT  NTMZBE  CASMZ  CASAVA RICES
  MZNUTS   0.072    0.015   0      -0.020   0.018   0      0

  MZCOWS   0.015    0.125   0       0.006   0.017   0      0
  PEANUT   0        0       0       0       0       0      0
  NTMZBE  -0.020    0.006   0       0.080  -0.001   0      0

  CASMZ    0.018    0.017   0      -0.001   0.179   0      0
  CASAVA   0        0       0       0       0       0      0
  RICES    0        0       0       0       0       0      0;
*-----------------------------------------------------------
```

```
TABLE VARCAS(I,IA)  variance-covariance of cassava
           MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA  RICES
  MZNUTS   0      0      0      0      0     0       0
  MZCOWS   0      0      0      0      0     0       0
  PEANUT   0      0      0      0      0     0       0
  NTMZBE   0      0      0      0      0     0       0
  CASMZ    0      0      0      0      3.654 0.482   0
  CASAVA   0      0      0      0      0.482 3.692   0
  RICES    0      0      0      0      0     0       0 ;
*-----------------------------------------------------------

TABLE VARNUT(I,IA)  variance-covariance of peanut
           MZNUTS MZCOWS PEANUT  NTMZBE CASMZ CASAVA RICES
   MZNUTS  0.083  0      0.002   0.013  0     0      0
   MZCOWS  0      0      0       0      0     0      0
   PEANUT  0.002  0      0.130   0.006  0     0      0
   NTMZBE  0.013  0      0.006   0.067  0     0      0
   CASMZ   0      0      0       0      0     0      0
   CASAVA  0      0      0       0      0     0      0
   RICES   0      0      0       0      0     0      0 ;
*-----------------------------------------------------------

TABLE VARBEA(I,IA)  variance-covariance of beans
           MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA RICES
   MZNUTS  0      0      0      0      0     0      0
   MZCOWS  0      0      0      0      0     0      0
   PEANUT  0      0      0      0      0     0      0
   NTMZBE  0      0      0      0.196  0     0      0
   CASMZ   0      0      0      0      0     0      0
   CASAVA  0      0      0      0      0     0      0
   RICES   0      0      0      0      0     0      0 ;
*-----------------------------------------------------------

TABLE VARCOW(I,IA)  variance-covariance of cowpea
           MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA RICES
   MZNUTS  0      0      0      0      0     0      0
   MZCOWS  0      0.052  0      0      0     0      0
   PEANUT  0      0      0      0      0     0      0
   NTMZBE  0      0      0      0      0     0      0
   CASMZ   0      0      0      0      0     0      0
   CASAVA  0      0      0      0      0     0      0
   RICES   0      0      0      0      0     0      0 ;
*-----------------------------------------------------------
TABLE VARRIC(I,IA)  variance-covariance of rice
           MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA RICES
   MZNUTS  0      0      0      0      0     0      0
   MZCOWS  0      0      0      0      0     0      0
   PEANUT  0      0      0      0      0     0      0
   NTMZBE  0      0      0      0      0     0      0
   CASMZ   0      0      0      0      0     0      0
   CASAVA  0      0      0      0      0     0      0
   RICES   0      0      0      0      0     0      0.228 ;
```

```
PARAMETER
     FERTIL(I)       tons of fertilizer per hectare
        /  MZNUTS      0
           MZCOWS      0
           PEANUT      0.025
           NTMZBE      0
           CASMZ       0.050
           CASAVA      0
           RICES       0.250 /;

*---------------------------------------------------------
*            OBJECTIVE FUNCTION COEFFICIENTS
*---------------------------------------------------------

PARAMETERS
  CCOST(I)        cash expenses in thousands of meticais
         / MZNUTS      25
           MZCOWS      18
           PEANUT      50
           NTMZBE      34
           CASMZ        5
           CASAVA      45
           RICES       80 /


  PCROP(J)    price per ton of crop j in thousands of meticais
         / MAIZE     1100
           CASAV     1150
           PNUTS     2000
           BEANS     1200
           COWPEA    850
           RRICE     1100 /

  ACOST(K)     animal production cost in thousands of meticais
         / CHICKS       1
           RABBIT       2
           AGOTS       10
           ACOWS      250
           APIGS       10
           DUCKS        2 /

  PANIM(K)    price per unit of animal in thousands of meticais
         / CHICKS       8
           RABBIT      15
           AGOTS       35
           ACOWS      600
           APIGS       20
           DUCKS        9 /
SCALAR     OFWR        off-farm wage rate per person-day /3.0/;
SCALAR     PFERT       thousands of meticais per ton    /1500/;
SCALAR     RISK        coefficient of risk aversion     /0.10/;
```

```
*----------------------------------------------------------------
*                    RESOURCES AVAILABLE
*----------------------------------------------------------------
SCALAR    LAND     hectares of land available          /5/;
SCALAR    FERTS    tons of fertilizer                 /0.5/;
SCALAR    MACHS    hours                              /50/;
*----------------------------------------------------------------
*                         LABOR
*----------------------------------------------------------------
* Total person-days availabe in the household is calculated
* by adding the working days in each month and multiply the
* number of people able to work in the household. Childs
* (teenagers) between 10 and 16 years old count for
* half person-day
*----------------------------------------------------------------
* TIME1 June        27 days  TIME3 December  25 days
*       July        28 days        January   28 days
*       August      28 days        February  25 days
*       total       83 days        total     78 days
*
* TIME2 September   27 days  TIME4 March     27 days
*       October     28 days        April     26 days
*       November    27 days        May       28 days
*       total       82 days        total     81 days
*----------------------------------------------------------------
*ADULAB=TOTAL DAYS*ADULT HOUSEHOLD MEMBERS
*CHILAB=TOTAL DAYS*CHILDS*0.5
*FEMLAB=TOTAL DAYS*FEMALE HOUSEHOLD MEMBERS
*MALAB =TOTAL DAYS*MALE HOUSEHOLD MEMBERS
*----------------------------------------------------------------
PARAMETERS
   TOTLAB(T)      total household labor available in period T
              / TIME1      641
                TIME2      574
                TIME3      556
                TIME4      567 /
   ADULAB(T)      adult household labor available in period T
              / TIME1      558
                TIME2      492
                TIME3      478
                TIME4      486 /
   CHILAB(T)      child household labor available in period T
              / TIME1       83
                TIME2       82
                TIME3       78
                TIME4       81 /

   FEMLAB(T)     female household labor available in period T
              / TIME1      441
                TIME2      410
                TIME3      390
                TIME4      405 /
```

```
  MALAB(T)        male household labor available in period T
                / TIME1        259
                  TIME2        246
                  TIME3        234
                  TIME4        243 /;

*------------------------------------------------------------
*                    MINIMUM FOOD REQUIREMENTS
*------------------------------------------------------------
PARAMETERS
     MCROP(J)        minimum food crop requirements in tons
               / MAIZE    0.020
                 CASAV    0.010
                 PNUTS    0.008
                 BEANS    0
                 COWPEA   0
                 RRICE    0 /
     MANIM(K)        minimum units of animal requirements
              /  CHICKS   1.0
                 RABBIT   0.5
                 AGOTS    0.25
                 ACOWS    0
                 APIGS    0
                 DUCKS    0 /;
VARIABLES
     X(I)      hectares of cropping system I
     XA(K)     units of animal k produced
     SALEC(J)  tons of crop j sold
     SALEA(K)  units of animal sold
     LABWF(T)  person-days of off-farm labor sold in period T
     MACHZ     hours
     FERTZ     tons of fertilizer
     Z         total net benefits in thousands meticais;

POSITIVE VARIABLES
     X(I)
     XA(K)
     SALEC(J)
     SALEA(K)
     FERTZ
     MACHZ
     LABWF(T);

EQUATIONS
     LANDS1    observe limits of land used
     LABF(T)   observe limits of labor use in period T
     WORK(T)   observe balance of off-farm labor
     FERT      observe limits of fertilizer use in period T
     MACH      observe limits of machinery use in period T
     MZBAL     observe balance of maize requirements
     CASBAL    observe balance of cassava requirements
     NUTBAL    observe balance of peanut requirements
```

```
     BEABAL    observe balance of beans requirements
     COWBAL    observe balance of cowpea requirements
     RICBAL    observe balance of cowpea requirements
     CHIBAL    observe balance of chicken requirements
     RABBAL    observe balance of rabbit requirements
     GOTBAL    observe balance of got requirements
     PIGBAL    observe balance of pig requirements
     LIVBAL    observe balance of cattle requirements
     DUKBAL    observe balance of ducks requirements
     SALAN1    animals sold
     SALAN2    animals sold
     SALAN3    animals sold
     SALAN4    animals sold
     SALAN5    animals sold
     SALAN6    animals sold
     OBJ       net revenue function;

LANDS1..       X('MZNUTS')+X('MZCOWS')+X('PEANUT')
              +X('NTMZBE')+X('CASMZ')+X('CASAVA')
              +X('RICES')                =L= LAND;

LABF(T)..  SUM(I, CLABOR(T,I)*X(I))+SUM(K, ALABOR(T,K)*XA(K))
               + LABWF(T)                =L= TOTLAB(T) ;

WORK(T)..  TOTLAB(T)-CHILAB(T)           =G= LABWF(T);

FERT..     SUM(I, FERTIL(I)*X(I))-FERTZ  =E= FERTS;

MACH..     SUM(I, MACHIN(I)*X(I))-MACHZ  =E= MACHS;

MZBAL..        SUM(I, MYIELD('MAIZE',I)*X(I))-SALEC('MAIZE')
              -RISK*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
              -RISK*SUM(I,X('MZCOWS')*X(I)*VARMZ(I,'MZCOWS'))
              -RISK*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
              -RISK*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
                                   =G= MCROP('MAIZE')*MEMB;

CASBAL..       SUM(I, MYIELD('CASAV',I)*X(I))-SALEC('CASAV')
              -RISK*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
              -RISK*SUM(I,X('CASAVA')*X(I)*VARMZ(I,'CASAVA'))
                                    =G=MCROP('CASAV')*MEMB;

NUTBAL..       SUM(I, MYIELD('PNUTS',I)*X(I))-SALEC('PNUTS')
              -RISK*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
              -RISK*SUM(I,X('PEANUT')*X(I)*VARMZ(I,'PEANUT'))
              -RISK*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
                                   =G= MCROP('PNUTS')*MEMB;

BEABAL..      SUM(I, MYIELD('BEANS',I)*X(I)) - SALEC('BEANS')
                                   =G= 0;
```

```
COWBAL..    SUM(I, MYIELD('COWPEA',I)*X(I)) - SALEC('COWPEA')
                                       =G= 0;

RICBAL..     SUM(I, MYIELD('RRICE',I)*X(I))  - SALEC('RRICE')
                                       =G= 0;

CHIBAL..       XA('CHICKS')    =G= MANIM('CHICKS')*MEMB ;

RABBAL..       XA('RABBIT')    =G= MANIM('RABBIT')*MEMB ;

GOTBAL..       XA('AGOTS')     =G= MANIM('AGOTS')*MEMB ;

LIVBAL..       XA('ACOWS')     =G= 0;

PIGBAL..       XA('APIGS')     =G= 0;

DUKBAL..       XA('DUCKS')     =G= 0;

SALAN1..       XA('CHICKS')-MANIM('CHICKS')*MEMB
                               =G= SALEA('CHICKS') ;

SALAN2..       XA('RABBIT')-MANIM('RABBIT')*MEMB
                               =G= SALEA('RABBIT') ;

SALAN3..       XA('AGOTS')-MANIM('AGOTS')*MEMB
                               =G= SALEA('AGOTS') ;

SALAN4..       XA('ACOWS')-MANIM('ACOWS')*MEMB
                               =G= SALEA('ACOWS') ;

SALAN5..       XA('APIGS')-MANIM('APIGS')*MEMB
                               =G= SALEA('APIGS') ;

SALAN6..       XA('DUCKS')-MANIM('DUCKS')*MEMB
                               =G= SALEA('DUCKS') ;

OBJ..     -SUM(I, X(I)*CCOST(I)) + SUM(J, SALEC(J)*PCROP(J))
           -SUM(K, XA(K)*ACOST(K))+SUM(K, SALEA(K)*PANIM(K))
           +SUM(T, LABWF(T)*OFWR)  =E= Z;

MODEL FIRMINO8  / LANDS1, LABF, WORK, FERT, MZBAL, CASBAL,
                  NUTBAL, BEABAL, COWBAL, RICBAL, CHIBAL,
                  RABBAL, GOTBAL, LIVBAL, PIGBAL, DUKBAL,
                  SALAN1, SALAN2, SALAN3, SALAN4, SALAN5,
                  SALAN6, OBJ /

SOLVE FIRMINO8 USING NLP MAXIMIZING Z;

DISPLAY   X.L, XA.L, SALEC.L, SALEA.L, LABWF.L, Z.L ,

          X.M, XA.M, SALEC.M, SALEA.M, LABWF.M, Z.M ;
```

GAMS MODEL FOR SIMULATIONS OF SCENARIOS

```
*
*     PROGRAMMING MODEL FOR FARM HOUSEHOLD EVALUATION
*                  FILE NAME: FIRMIN8A.GMS
*
*------------------------------------------------------------
*                    FAMILY COMPOSITION
*------------------------------------------------------------
SCALAR    MEMB total members of the family    /8/;
SCALAR    CHIL total number of children       /2/;
SCALAR    FEMA total female members           /5/;
SCALAR    MALE total male members             /3/;
*------------------------------------------------------------
*                  DEFINITION OF INDEXES
*-------------------------------------------------------------
SETS I    cropping systems
     / MZNUTS, MZCOWS, PEANUT,NTMZBE, CASMZ,
      CASAVA, RICES /

     J    crops
     /MAIZE, CASAV, PNUTS, BEANS,
      COWPEA, RRICE/

     T    time periods
     /TIME1, TIME2, TIME3, TIME4/

     K    animal production
     /CHICKS, RABBIT, AGOTS, ACOWS,
      APIGS, DUCKS/;
*-------------------------------------------------------------
*                    TECHNICAL MATRIX
*-------------------------------------------------------------

ALIAS(I,IA);

TABLE LANDR(J,I)   mean land ratio per cropping system
          MZNUTS  MZCOWS PEANUT   NTMZBE CASMZ CASAVA RICES
 MAIZE      0.6     0.6     0       0.4    0.6    0      0
 CASAV      0       0       0       0      0.4    1      0
 PNUTS      0.4     0       1       0.3    0      0      0
 BEANS      0       0       0       0.3    0      0      0
 COWPEA     0       0.4     0       0      0      0      0
 RRICE      0       0       0       0      0      0      1;
*-------------------------------------------------------------
TABLE CLABOR(T,I)   labor requirements in person-days
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA  RICES
 TIME1   20       0      35      25     5     15       0
 TIME2   15      15      20      20    20     10      45
 TIME3   10      20      10      15    10     20      40
 TIME4    0      20       0      10     5      5      25 ;
*-------------------------------------------------------------
```

```
TABLE ALABOR(T,K)   labor requirements in person-days
          CHICKS RABBIT AGOTS   ACOWS   APIGS   DUCKS
  TIME1    3.5    7.5   60.0    115.0   10.0     4.5
  TIME2    3.5    7.5   45.0     95.0   10.0     4.5
  TIME3    3.5    7.5   45.0     95.0   10.0     4.5
  TIME4    3.5    7.5   60.0    115.0   10.0     4.5 ;
*------------------------------------------------------------

TABLE MACHIN(T,I)   machinery use in hours per hectare
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA  RICES
 TIME1   3.6      0     5.5     3.6    3.6  5.5     6.5
 TIME2   0        0     0       0      0    0       1.0
 TIME3   0        0     0       0      0    0       0
 TIME4   0        0     0       0      0    0       0  ;
*------------------------------------------------------------

TABLE MYIELD(J,I)   per hectare mean crop yields in tons
          MZNUTS  MZCOWS PEANUT   NTMZBE CASMZ CASAVA RICES
 MAIZE    0.672   0.568   0       0.587  0.496  0      0
 CASAV    0       0       0       0      2.070  3.233  0
 PNUTS    0.530   0       0.713   0.531  0      0      0
 BEANS    0       0       0       0.616  0      0      0
 COWPEA   0       0.319   0       0      0      0      0
 RRICE    0       0       0       0      0      0      0.523;

*------------------------------------------------------------
*                    VARIANCE MATRIX
*------------------------------------------------------------

TABLE VARMZ(I,IA)   variance-covariance of maize
          MZNUTS   MZCOWS  PEANUT  NTMZBE  CASMZ  CASAVA RICES
  MZNUTS   0.072   0.015   0      -0.020   0.018   0      0
  MZCOWS   0.015   0.125   0       0.006   0.017   0      0
  PEANUT   0       0       0       0       0       0      0
  NTMZBE  -0.020   0.006   0       0.080  -0.001   0      0
  CASMZ    0.018   0.017   0      -0.001   0.179   0      0
  CASAVA   0       0       0       0       0       0      0
  RICES    0       0       0       0       0       0      0;
*------------------------------------------------------------

TABLE VARCAS(I,IA)  variance-covariance of cassava
           MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA  RICES
  MZNUTS    0      0      0      0      0      0      0
  MZCOWS    0      0      0      0      0      0      0
  PEANUT    0      0      0      0      0      0      0
  NTMZBE    0      0      0      0      0      0      0
  CASMZ     0      0      0      0      3.654  0.482  0
  CASAVA    0      0      0      0      0.482  3.692  0
  RICES     0      0      0      0      0      0      0 ;
*------------------------------------------------------------
```

```
TABLE VARNUT(I,IA)  variance-covariance of peanut
        MZNUTS MZCOWS  PEANUT  NTMZBE CASMZ CASAVA RICES
   MZNUTS  0.083   0       0.002   0.013   0      0      0
   MZCOWS  0       0       0       0       0      0      0
   PEANUT  0.002   0       0.130   0.006   0      0      0
   NTMZBE  0.013   0       0.006   0.067   0      0      0
   CASMZ   0       0       0       0       0      0      0
   CASAVA  0       0       0       0       0      0      0
   RICES   0       0       0       0       0      0      0 ;
*----------------------------------------------------------

TABLE VARBEA(I,IA)  variance-covariance of beans
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA RICES
   MZNUTS  0      0      0      0      0      0      0
   MZCOWS  0      0      0      0      0      0      0
   PEANUT  0      0      0      0      0      0      0
   NTMZBE  0      0      0      0.196  0      0      0
   CASMZ   0      0      0      0      0      0      0
   CASAVA  0      0      0      0      0      0      0
   RICES   0      0      0      0      0      0      0 ;
*----------------------------------------------------------

TABLE VARCOW(I,IA)  variance-covariance of cowpea
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA RICES
   MZNUTS  0      0      0      0      0      0      0
   MZCOWS  0      0.052  0      0      0      0      0
   PEANUT  0      0      0      0      0      0      0
   NTMZBE  0      0      0      0      0      0      0
   CASMZ   0      0      0      0      0      0      0
   CASAVA  0      0      0      0      0      0      0
   RICES   0      0      0      0      0      0      0 ;
*----------------------------------------------------------

TABLE VARRIC(I,IA)  variance-covariance of rice
        MZNUTS MZCOWS PEANUT NTMZBE CASMZ CASAVA RICES
   MZNUTS  0      0      0      0      0    0      0
   MZCOWS  0      0      0      0      0    0      0
   PEANUT  0      0      0      0      0    0      0
   NTMZBE  0      0      0      0      0    0      0
   CASMZ   0      0      0      0      0    0      0
   CASAVA  0      0      0      0      0    0      0
   RICES   0      0      0      0      0    0      0.228 ;

PARAMETER
     FERTIL(I)      tons of fertilizer per hectare
        /  MZNUTS     0
           MZCOWS     0
           PEANUT     0.025
           NTMZBE     0
           CASMZ      0.050
           CASAVA     0
           RICES      0.250 /;
```

```
*------------------------------------------------------------
*           OBJECTIVE FUNCTION COEFFICIENTS
*------------------------------------------------------------
PARAMETERS
  CCOST(I)        cash expenses in thousands of meticais
        / MZNUTS      25
          MZCOWS      18
          PEANUT      50
          NTMZBE      34
          CASMZ        5
          CASAVA      45
          RICES       80 /
  PCROP(J)    price per ton of crop j in thousands of meticais
        / MAIZE     1100
          CASAV     1150
          PNUTS     2000
          BEANS     1200
          COWPEA    850
          RRICE     1100 /
  ACOST(K)    animal production cost in thousands of meticais
        / CHICKS       1
          RABBIT       2
          AGOTS       10
          ACOWS      250
          APIGS       10
          DUCKS        2 /
  PANIM(K)    price per unit of animal in thousands of meticais
        / CHICKS       8
          RABBIT      15
          AGOTS       35
          ACOWS      600
          APIGS       20
          DUCKS        9 /

SCALAR    OFWR      off-farm wage rate per person-day /3.0/;
SCALAR    PFERT     thousands of meticais per ton    /1500/;
SCALAR    RISK1     coefficient of risk aversion     /0.00/;
SCALAR    RISK2     coefficient of risk aversion     /0.50/;
SCALAR    RISK3     coefficient of risk aversion     /1.00/;
SCALAR    RISK4     coefficient of risk aversion     /1.50/;
SCALAR    RISK5     coefficient of risk aversion     /2.00/;

*------------------------------------------------------------
*                  RESOURCES AVAILABLE
*------------------------------------------------------------
SCALAR    LAND      hectares of land available         /5/;
SCALAR    FERTS     tons of fertilizer                 /0.5/;
SCALAR    MACHS     hours                              /50/;
*------------------------------------------------------------
```

```
*                              LABOR
*-----------------------------------------------------------
* Total person-days availabe in the household is calculated
* by adding the working days in each month and multiply the
* number of people able to work in the household. Childs
* (teenagers) between 10 and 16 years old count for
* half person-day
*-----------------------------------------------------------
* TIME1 June        27 days  TIME3 December  25 days
*       July        28 days        January   28 days
*       August      28 days        February  25 days
*       total       83 days        total     78 days
*
* TIME2 September   27 days  TIME4 March     27 days
*       October     28 days        April     26 days
*       November    27 days        May       28 days
*       total       82 days        total     81 days
*-----------------------------------------------------------
*ADULAB=TOTAL DAYS*ADULT HOUSEHOLD MEMBERS
*CHILAB=TOTAL DAYS*CHILDS*0.5
*FEMLAB=TOTAL DAYS*FEMALE HOUSEHOLD MEMBERS
*MALAB =TOTAL DAYS*MALE HOUSEHOLD MEMBERS
*-----------------------------------------------------------
PARAMETERS

 TOTLAB(T)      total household labor available in period T
              / TIME1      641
                TIME2      574
                TIME3      556
                TIME4      567 /
 ADULAB(T)      adult household labor available in period T
              / TIME1      558
                TIME2      492
                TIME3      478
                TIME4      486 /
 CHILAB(T)      child household labor available in period T
              / TIME1       83
                TIME2       82
                TIME3       78
                TIME4       81 /
 FEMLAB(T)     female household labor available in period T
              / TIME1      441
                TIME2      410
                TIME3      390
                TIME4      405 /
 MALAB(T)       male household labor available in period T
              / TIME1      259
                TIME2      246
                TIME3      234
                TIME4      243 /;

*-----------------------------------------------------------
```

```
*                    MINIMUM FOOD REQUIREMENTS
*-----------------------------------------------------------------
PARAMETERS
     MCROP(J)        minimum food crop requirements in tons
             / MAIZE    0.020
               CASAV    0.010
               PNUTS    0.008
               BEANS    0
               COWPEA   0
               RRICE    0 /

     MANIM(K)        minimum units of animal requirements
            /  CHICKS   1.0
               RABBIT   0.5
               AGOTS    0.25
               ACOWS    0
               APIGS    0
               DUCKS    0 /;

VARIABLES
     X(I)      hectares of cropping system I
     XA(K)     units of animal k produced
     SALEC(J)  tons of crop j sold
     SALEA(K)  units of animal sold
     LABWF(T)  person-days of off-farm labor sold in period T
     MACHZ     hours
     FERTZ     tons of fertilizer
     Z         total net benefits in thousands meticais;


POSITIVE VARIABLES
     X(I)
     XA(K)
     SALEC(J)
     SALEA(K)
     FERTZ
     MACHZ
     LABWF(T);


EQUATIONS
     LANDS1    observe limits of land used
     LABF(T)   observe limits of labor use in period T
     WORK(T)   observe balance of off-farm labor
     FERT      observe limits of fertilizer use in period T
     MACH      observe limits of machinery use in period T
     MZBAL1    observe balance of maize requirements
     CASBAL1   observe balance of cassava requirements
     NUTBAL1   observe balance of peanut requirements
     MZBAL2    observe balance of maize requirements
     CASBAL2   observe balance of cassava requirements
     NUTBAL2   observe balance of peanut requirements
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     MZBAL3    observe balance of maize requirements
     CASBAL3   observe balance of cassava requirements
     NUTBAL3   observe balance of peanut requirements
     MZBAL4    observe balance of maize requirements
     CASBAL4   observe balance of cassava requirements
     NUTBAL4   observe balance of peanut requirements
     MZBAL5    observe balance of maize requirements
     CASBAL5   observe balance of cassava requirements
     NUTBAL5   observe balance of peanut requirements
     BEABAL    observe balance of beans requirements
     COWBAL    observe balance of cowpea requirements
     RICBAL    observe balance of cowpea requirements
     CHIBAL    observe balance of chicken requirements
     RABBAL    observe balance of rabbit requirements
     GOTBAL    observe balance of got requirements
     PIGBAL    observe balance of pig requirements
     LIVBAL    observe balance of cattle requirements
     DUKBAL    observe balance of ducks requirements
     SALAN1    animals sold
     SALAN2    animals sold
     SALAN3    animals sold
     SALAN4    animals sold
     SALAN5    animals sold
     SALAN6    animals sold
     OBJ       net revenue function;

LANDS1..       X('MZNUTS')+X('MZCOWS')+X('PEANUT')
              +X('NTMZBE')+X('CASMZ')+X('CASAVA')
              +X('RICES')       =L= LAND;

LABF(T)..  SUM(I, CLABOR(T,I)*X(I))+SUM(K, ALABOR(T,K)*XA(K))
                          + LABWF(T)       =L= TOTLAB(T) ;

WORK(T)..      TOTLAB(T)-CHILAB(T)         =G= LABWF(T);

FERT..     SUM(I, FERTIL(I)*X(I))-FERTZ  =E= FERTS;

MACH..     SUM(I, MACHIN(I)*X(I))-MACHZ  =E= MACHS;

MZBAL1..       SUM(I, MYIELD('MAIZE',I)*X(I))-SALEC('MAIZE')
              -RISK1*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
              -RISK1*SUM(I,X('MZCOWS')*X(I)*VARMZ(I,'MZCOWS'))
              -RISK1*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
               -RISK1*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
                                    =G= MCROP('MAIZE')*MEMB;

CASBAL1..      SUM(I, MYIELD('CASAV',I)*X(I))-SALEC('CASAV')
               -RISK1*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
              -RISK1*SUM(I,X('CASAVA')*X(I)*VARMZ(I,'CASAVA'))
                                     =G= MCROP('CASAV')*MEMB;
```

```
NUTBAL1..     SUM(I, MYIELD('PNUTS',I)*X(I))-SALEC('PNUTS')
             -RISK1*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
             -RISK1*SUM(I,X('PEANUT')*X(I)*VARMZ(I,'PEANUT'))
             -RISK1*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
                                    =G= MCROP('PNUTS')*MEMB;

MZBAL2..      SUM(I, MYIELD('MAIZE',I)*X(I))-SALEC('MAIZE')
             -RISK2*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
             -RISK2*SUM(I,X('MZCOWS')*X(I)*VARMZ(I,'MZCOWS'))
             -RISK2*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
             -RISK2*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
                                    =G= MCROP('MAIZE')*MEMB;

CASBAL2..     SUM(I, MYIELD('CASAV',I)*X(I))-SALEC('CASAV')
             -RISK2*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
             -RISK2*SUM(I,X('CASAVA')*X(I)*VARMZ(I,'CASAVA'))
                                    =G= MCROP('CASAV')*MEMB;

NUTBAL2..     SUM(I, MYIELD('PNUTS',I)*X(I))-SALEC('PNUTS')
             -RISK2*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
             -RISK2*SUM(I,X('PEANUT')*X(I)*VARMZ(I,'PEANUT'))
             -RISK2*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
                                    =G= MCROP('PNUTS')*MEMB;

MZBAL3..      SUM(I, MYIELD('MAIZE',I)*X(I))-SALEC('MAIZE')
             -RISK3*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
             -RISK3*SUM(I,X('MZCOWS')*X(I)*VARMZ(I,'MZCOWS'))
             -RISK3*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
             -RISK3*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
                                    =G= MCROP('MAIZE')*MEMB;

CASBAL3..     SUM(I, MYIELD('CASAV',I)*X(I))-SALEC('CASAV')
             -RISK3*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
             -RISK3*SUM(I,X('CASAVA')*X(I)*VARMZ(I,'CASAVA'))
                                    =G= MCROP('CASAV')*MEMB;

NUTBAL3..     SUM(I, MYIELD('PNUTS',I)*X(I))-SALEC('PNUTS')
             -RISK3*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
             -RISK3*SUM(I,X('PEANUT')*X(I)*VARMZ(I,'PEANUT'))
             -RISK3*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
                                    =G= MCROP('PNUTS')*MEMB;

MZBAL4..      SUM(I, MYIELD('MAIZE',I)*X(I))-SALEC('MAIZE')
             -RISK4*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
             -RISK4*SUM(I,X('MZCOWS')*X(I)*VARMZ(I,'MZCOWS'))
             -RISK4*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
             -RISK4*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
                                    =G= MCROP('MAIZE')*MEMB;
```

```
CASBAL4..      SUM(I, MYIELD('CASAV',I)*X(I))-SALEC('CASAV')
              -RISK4*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
              -RISK4*SUM(I,X('CASAVA')*X(I)*VARMZ(I,'CASAVA'))
                                    =G= MCROP('CASAV')*MEMB;

NUTBAL4..      SUM(I, MYIELD('PNUTS',I)*X(I))-SALEC('PNUTS')
              -RISK4*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
              -RISK4*SUM(I,X('PEANUT')*X(I)*VARMZ(I,'PEANUT'))
              -RISK4*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
                                  =G= MCROP('PNUTS')*MEMB;

MZBAL5..       SUM(I, MYIELD('MAIZE',I)*X(I))-SALEC('MAIZE')
              -RISK5*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
              -RISK5*SUM(I,X('MZCOWS')*X(I)*VARMZ(I,'MZCOWS'))
              -RISK5*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
              -RISK5*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
                                   =G= MCROP('MAIZE')*MEMB;

CASBAL5..      SUM(I, MYIELD('CASAV',I)*X(I))-SALEC('CASAV')
              -RISK5*SUM(I,X('CASMZ')*X(I)*VARMZ(I,'CASMZ'))
              -RISK5*SUM(I,X('CASAVA')*X(I)*VARMZ(I,'CASAVA'))
                                    =G= MCROP('CASAV')*MEMB;

NUTBAL5..      SUM(I, MYIELD('PNUTS',I)*X(I))-SALEC('PNUTS')
              -RISK5*SUM(I,X('MZNUTS')*X(I)*VARMZ(I,'MZNUTS'))
              -RISK5*SUM(I,X('PEANUT')*X(I)*VARMZ(I,'PEANUT'))
              -RISK5*SUM(I,X('NTMZBE')*X(I)*VARMZ(I,'NTMZBE'))
                                  =G= MCROP('PNUTS')*MEMB;

BEABAL..    SUM(I, MYIELD('BEANS',I)*X(I)) - SALEC('BEANS')
                                           =G= 0;

COWBAL..    SUM(I, MYIELD('COWPEA',I)*X(I)) - SALEC('COWPEA')
                                           =G= 0;

RICBAL..    SUM(I, MYIELD('RRICE',I)*X(I)) - SALEC('RRICE')
                                           =G= 0;

CHIBAL..       XA('CHICKS')   =G= MANIM('CHICKS')*MEMB ;

RABBAL..       XA('RABBIT')   =G= MANIM('RABBIT')*MEMB ;

GOTBAL..       XA('AGOTS')    =G= MANIM('AGOTS')*MEMB ;

LIVBAL..       XA('ACOWS')    =G= 0;

PIGBAL..       XA('APIGS')    =G= 0;
```

```
DUKBAL..        XA('DUCKS')     =G= 0;

SALAN1..        XA('CHICKS')-MANIM('CHICKS')*MEMB
                            =G= SALEA('CHICKS') ;
SALAN2..        XA('RABBIT')-MANIM('RABBIT')*MEMB
                            =G= SALEA('RABBIT') ;

SALAN3..        XA('AGOTS')-MANIM('AGOTS')*MEMB
                            =G= SALEA('AGOTS') ;

SALAN4..        XA('ACOWS')-MANIM('ACOWS')*MEMB
                            =G= SALEA('ACOWS') ;

SALAN5..        XA('APIGS')-MANIM('APIGS')*MEMB
                            =G= SALEA('APIGS') ;

SALAN6..        XA('DUCKS')-MANIM('DUCKS')*MEMB
                            =G= SALEA('DUCKS') ;

OBJ..     -SUM(I, X(I)*CCOST(I)) + SUM(J, SALEC(J)*PCROP(J))
          -SUM(K, XA(K)*ACOST(K))+SUM(K, SALEA(K)*PANIM(K))
          +SUM(T, LABWF(T)*OFWR)  =E= Z;

MODEL FIRMI8A1  / LANDS1, LABF, WORK, FERT, MZBAL1, CASBAL1,
                  NUTBAL1, BEABAL, COWBAL, RICBAL, CHIBAL,
                  RABBAL, GOTBAL, LIVBAL, PIGBAL, DUKBAL,
                  SALAN1, SALAN2, SALAN3, SALAN4, SALAN5,
                  SALAN6, OBJ /

SOLVE FIRMI8A1 USING NLP MAXIMIZING Z;

DISPLAY   X.L, XA.L, SALEC.L, SALEA.L, LABWF.L, Z.L ,

          X.M, XA.M, SALEC.M, SALEA.M, LABWF.M, Z.M ;

MODEL FIRMI8A2  / LANDS1, LABF, WORK, FERT, MZBAL2, CASBAL2,
                  NUTBAL2, BEABAL, COWBAL, RICBAL, CHIBAL,
                  RABBAL, GOTBAL, LIVBAL, PIGBAL, DUKBAL,
                  SALAN1, SALAN2, SALAN3, SALAN4, SALAN5,
                  SALAN6, OBJ /

SOLVE FIRMI8A2 USING NLP MAXIMIZING Z;

DISPLAY   X.L, XA.L, SALEC.L, SALEA.L, LABWF.L, Z.L ,

          X.M, XA.M, SALEC.M, SALEA.M, LABWF.M, Z.M ;

MODEL FIRMI8A3  / LANDS1, LABF, WORK, FERT, MZBAL3, CASBAL3,
                  NUTBAL3, BEABAL, COWBAL, RICBAL, CHIBAL,
                  RABBAL, GOTBAL, LIVBAL, PIGBAL, DUKBAL,
                  SALAN1, SALAN2, SALAN3, SALAN4, SALAN5,
                  SALAN6, OBJ /
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SOLVE FIRMI8A3 USING NLP MAXIMIZING Z;

DISPLAY   X.L, XA.L, SALEC.L, SALEA.L, LABWF.L, Z.L ,

          X.M, XA.M, SALEC.M, SALEA.M, LABWF.M, Z.M ;

MODEL FIRMI8A4  / LANDS1, LABF, WORK, FERT, MZBAL4, CASBAL4,
                  NUTBAL4, BEABAL, COWBAL, RICBAL, CHIBAL,
                  RABBAL, GOTBAL, LIVBAL, PIGBAL, DUKBAL,
                  SALAN1, SALAN2, SALAN3, SALAN4, SALAN5,
                  SALAN6, OBJ /

SOLVE FIRMI8A4 USING NLP MAXIMIZING Z;

DISPLAY   X.L, XA.L, SALEC.L, SALEA.L, LABWF.L, Z.L ,

          X.M, XA.M, SALEC.M, SALEA.M, LABWF.M, Z.M ;

MODEL FIRMI8A5  / LANDS1, LABF, WORK, FERT, MZBAL5, CASBAL5,
                  NUTBAL5, BEABAL, COWBAL, RICBAL, CHIBAL,
                  RABBAL, GOTBAL, LIVBAL, PIGBAL, DUKBAL,
                  SALAN1, SALAN2, SALAN3, SALAN4, SALAN5,
                  SALAN6, OBJ /

SOLVE FIRMI8A5 USING NLP MAXIMIZING Z;

DISPLAY   X.L, XA.L, SALEC.L, SALEA.L, LABWF.L, Z.L ,

          X.M, XA.M, SALEC.M, SALEA.M, LABWF.M, Z.M ;
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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